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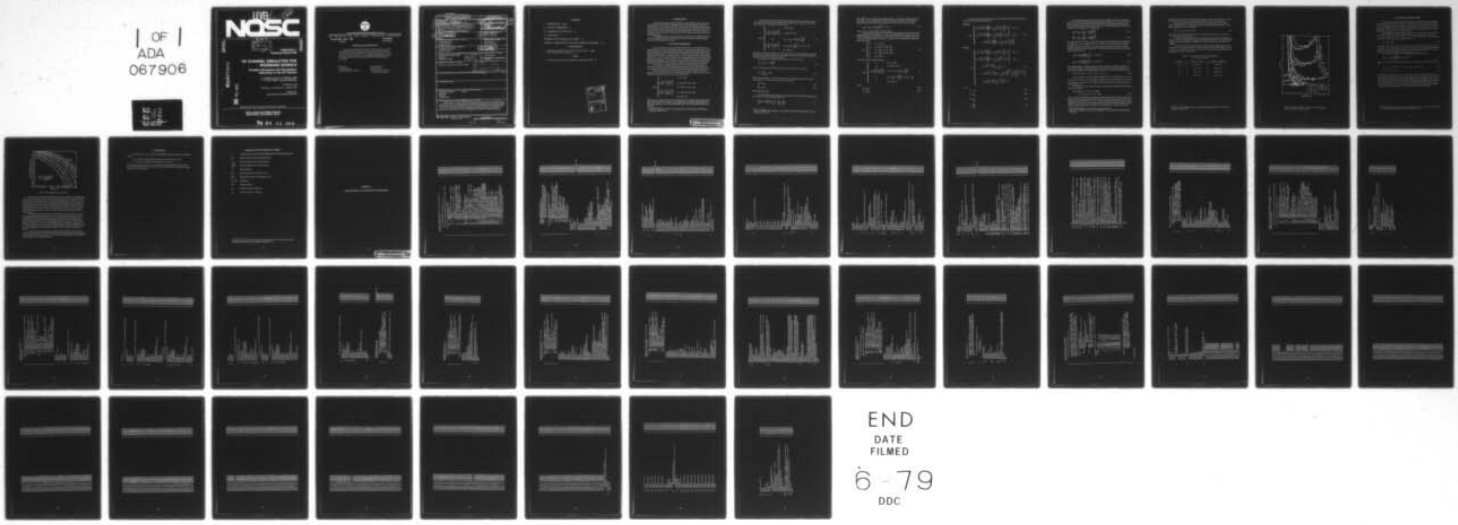

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Addendum 1
Technical Report 208

HF CHANNEL SIMULATOR FOR WIDEBAND SIGNALS

Deviative Absorption and Groundwave Attenuation in the HF Channel

R. Lugannani and H. G. Booker, CSC
L. E. Hoff, NOSC (Contract Monitor)

6 November 1978

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In NOSC TR 208, of 31 March 1978, a mathematical model of the wideband HF channel was developed and a software version of the model was presented. This addendum augments that model by including deviative absorption loss for the skywave returns and by providing for automatic calculation of the groundwave attenuation. With these additions, the model more accurately portrays the HF channel and has increased utility. A software version of the revised channel model is implemented and a listing of the program is appended.

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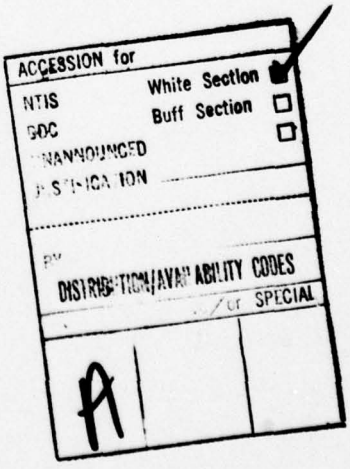

I. INTRODUCTION

This addendum augments NOSC TR 208 (ref. 1) and should be read in conjunction with that report. In the report, a mathematical model of the wideband HF channel was developed and used for computer simulation of the channel. The purpose of this addendum is to augment the existing channel model by adding (1) a deviative absorption term for the skywave returns, and (2) an attenuation term for the groundwave. With these additions the mathematical model will more accurately portray the HF channel and its utility will be considerably enhanced.

In the following sections the two additions are described and a FORTRAN listing of the revised simulator is provided. Notations and definitions used are, wherever possible, identical to those appearing in the report.

II. DEVIATIVE ABSORPTION

The earlier channel model incorporated only three sources of attenuation for the skywave returns. These were nondeviative absorption, antenna gain and spreading ($1/r^2$) loss. Several less-important sources of attenuation, such as polarization mismatch, focusing and deviative absorption, were not included. While the losses due to these other sources are relatively small, one of them – deviative absorption – plays an important role in signal analysis applications. Both the deviative absorption loss and the signal distortion are greater for high-angle returns than they are for low-angle returns. If deviative absorption is not included in the model, the high-angle returns will have an exaggerated effect on the overall received signal, and this may lead to a more pessimistic evaluation of the channel than is warranted.

In what follows, a tractable approximation for the deviative absorption loss is described and sample calculations using this approximation are presented. We begin with some notation and assumptions; all of which have been discussed in greater detail in (ref. 1).

The electron density profile is assumed to have a parabolic shape in the E and F regions; no provision has been made for daytime splitting of the F region into distinct F_1 and F_2 regions. The nighttime electron density profile is given by

$$N(h) = \begin{cases} 0, & h < h_E - 2H_E \\ N_E\left[1 - \left(\dfrac{h - h_E}{2H_E}\right)^2\right], & h_E - 2H_E \leq h \leq h_E + 2H_E \\ 0, & h_E + 2H_E < h < h_F - 2H_F \\ N_F\left[1 - \left(\dfrac{h - h_F}{2H_F}\right)^2\right], & h_F - 2H_F \leq h \leq h_F + 2H_F \\ 0, & h_F + 2H_F < h \end{cases} \quad (1)$$

Here, N_E is the peak electron density (free electrons per m^3) of the E region while h_E is the height of the peak electron density in the E region in km, and $2H_E$ is the semithickness of the E region parabola in km. Similar definitions apply to the F region parameters N_F, h_F and $2H_F$.

1. NOSC TR 208, HF Channel Simulator for Wideband Signals (U), by R Lugannani and HG Booker, Unclassified, 31 March 1978.

For the daytime electron density profile, allowance is made for ionization between the E and F regions. Between these regions the electron density is assumed to be constant and equal to N_E. For the daytime profile we have,

$$N(h) = \begin{cases} 0 \quad , & h < h_E - 2H_E \\ N_E\left[1 - \left(\frac{h - h_E}{2H_E}\right)^2\right], & h - 2H_E \leq h \leq h_E \\ N_E \quad , & h_E < h < h_F + 2H_F\left(1 - \frac{N_E}{N_F}\right)^{1/2} \\ N_F\left[1 - \left(\frac{h - h_F}{2H_F}\right)^2\right], & h_F + 2H_F\left(1 - \frac{N_E}{N_F}\right)^{1/2} \leq h \leq h_F + 2H_F \\ 0 \quad , & h_F + 2H_F < h \end{cases} \tag{2}$$

The constants appearing in equation (2) are defined in the same manner as they were for the nighttime case, except that their values will be different because of the different heights and ionization densities in the daytime ionosphere.

In the absence of a magnetic field, the refractive index is given by,

$$\mu^2 = \mu^2(h) = 1 - K\frac{N(h)}{f^2} \tag{3}$$

where f is the frequency in Hz, N(h) is given by either equation (1) or (2), and,

$$K = \frac{e^2}{4\pi^2 \epsilon_o m} \cong 80.5. \tag{4}$$

The penetration frequency for each region is defined as the plasma frequency at the peak electron density. For the E and F regions, these are given by,

$$f_{pE}^2 = KN_E \tag{5a}$$

$$f_{pF}^2 = KN_F \tag{5b}$$

with f_{pE} and f_{pF} in Hz.

For vertical incidence in the absence of a magnetic field, the following expression will be used for the deviative absorption loss (ref. 2)

$$L_{dev}^{(vert)}(f) = \left(\frac{8.686}{c}\right)\int_0^{h_r} \nu \cdot \left[\frac{1}{\mu} - \mu\right] dh. \tag{6}$$

2. Davies, K., Ionospheric Radio Propagation, in National Bureau of Standards Monograph 80, U. S. Government Printing Office, 1965.

Here, $L_{dev}^{(vert)}(f)$ is the attenuation in decibels per hop, $\nu = \nu(h)$ is the collision frequency in Hz, c is the velocity of light in km/sec and h_r is the height at which $\mu = 0$. In the case of oblique incidence the deviative loss is obtained from (6) by means of the relationship

$$L_{dev} = L_{dev}(f) = \frac{1}{\cos\theta} L_{dev}^{(vert)}(f \cdot \cos\theta) \tag{7}$$

where θ is the ray angle measured from the vertical.

The integration in equation (6) is difficult to perform because of the presence of the collision frequency in the integrand. To overcome this difficulty the integrand will be simplified by taking the collision frequency to be constant in the E and F regions and allowing it to decrease exponentially between the two regions. Thus, for the nighttime collision frequency, we will use,

$$\nu(h) = \begin{cases} 0, & h < h_E - 2H_E \\ \nu_E, & h_E - 2H_E \leq h \leq h_E + 2H_E \\ 0, & h_E + 2H_E < h < h_F - 2H_F \\ \nu_F, & h_F - 2H_F \leq h \leq h_F + 2H_F \\ 0, & h_F + 2H_F < h, \end{cases} \tag{8}$$

and for the daytime collision frequency,

$$\nu(h) = \begin{cases} 0 & , \quad h < h_E - 2H_E \\ \nu_E & , \quad h_E - 2H_E \leq h \leq h_E \\ \nu_E \exp\left[-\left(\frac{h - h_E}{2H_E}\right)\right], & h_E < h < h_F + 2H_F \left(1 - \frac{N_E}{N_F}\right)^{1/2} \\ \nu_F & , \quad h_F + 2H_F \left(1 - \frac{N_E}{N_F}\right)^{1/2} \leq h \leq h_F + 2H_F \\ 0 & , \quad h_F + 2H_F < h \end{cases} \tag{9}$$

where

$$\nu_E = \nu(h_E) \tag{10a}$$

$$\nu_F = \nu(h_F) \tag{10b}$$

Substituting equations (8) and (9) into (6), performing the integration and using (7) we obtain for the deviative absorption loss:

Nighttime

$$L_{dev} = \begin{cases} 8.686 \left(\frac{\nu_E \cdot H_E}{2c \cdot x}\right)\left[\left(\hat{f}_E x + \frac{1}{\hat{f}_E x}\right) \ln\left(\frac{1+\hat{f}_E x}{1-\hat{f}_E x}\right) - 2\right], & \hat{f}_E x \leqslant 1 \\ 8.686 \left(\frac{\nu_E \cdot H_E}{c \cdot x}\right)\left[\left(\hat{f}_E x + \frac{1}{\hat{f}_E x}\right) \ln\left(\frac{\hat{f}_E x + 1}{\hat{f}_E x - 1}\right) - 2\right], & \hat{f}_E x > 1 \\ \quad + 8.686 \left(\frac{\nu_F \cdot H_F}{2c \cdot x}\right)\left[\left(\hat{f}_F x + \frac{1}{\hat{f}_F x}\right) \ln\left(\frac{1+\hat{f}_F x}{1-\hat{f}_F x}\right)\right] \end{cases} \tag{11}$$

Daytime

$$L_{dev} = \begin{cases} 8.686 \left(\frac{\nu_E \cdot H_E}{2c \cdot x}\right)\left[\left(\hat{f}_E x + \frac{1}{\hat{f}_E x}\right) \ln\left(\frac{1+\hat{f}_E x}{1-\hat{f}_E x}\right) - 2\right], & \hat{f}_E x \leqslant 1 \\ 8.686 \left(\frac{\nu_E \cdot H_E}{2c \cdot x}\right)\left[\left(\hat{f}_E x + \frac{1}{\hat{f}_E x}\right) \ln\left(\frac{\hat{f}_E x + 1}{\hat{f}_E x - 1}\right) - 2\right], & \hat{f}_E x > 1 \\ \quad + 8.686 \left(\frac{\nu_E \cdot H_E}{c \cdot x}\right) \frac{1}{\hat{f}_E x \left(\hat{f}_E^2 x^2 - 1\right)^{1/2}} \\ \quad + 8.686 \left(\frac{\nu_F \cdot H_F}{c \cdot x}\right) \cdot \left(\hat{f}_F x + \frac{1}{\hat{f}_F x}\right) \ln\left(\frac{\sqrt{1-r^2} + \sqrt{\hat{f}_F^2 x^2 - r^2}}{\sqrt{1-\hat{f}_F^2 x^2}}\right) \\ \quad - 8.686 \left(\frac{\nu_F \cdot H_F}{c \cdot x}\right) \frac{\sqrt{1-r^2}}{\hat{f}_F x} \sqrt{\hat{f}_F^2 x^2 - r^2} \end{cases} \tag{12}$$

with,

$$x = \cos\theta \tag{13}$$

$$\hat{f}_E = \frac{f}{f_{pE}} \tag{14a}$$

$$\hat{f}_F = \frac{f}{f_{pF}} \tag{14b}$$

$$r^2 = \frac{f_{pE}^2}{f_{pF}^2} \tag{15}$$

In the foregoing analysis, the effect of the earth's magnetic field has been neglected, but we take this to be an adequate approximation for the ordinary wave. For the extraordinary wave, the penetration frequencies are shifted relative to those for the ordinary wave and it is essential to take this into account. As in (ref. 1) the extraordinary wave penetration, frequencies are obtained using the relationships,

$$f_{pE}^{(x)} = \frac{1}{2} f_{HE} + \left[f_{HE}^2 + 4 \left(f_{pE}^{(0)} \right)^2 \right]^{1/2} \tag{16a}$$

$$f_{pF}^{(x)} = \frac{1}{2} f_{HF} + \left[f_{HF}^2 + 4 \left(f_{pF}^{(0)} \right)^2 \right]^{1/2}. \tag{16b}$$

Here, the superscripts "0" and "x" denote the ordinary and extraordinary waves respectively, with $f_{pE}^{(0)}$ given by (5a) and $f_{pF}^{(0)}$ given by (5b). The frequencies f_{HE} and f_{HF} are the gyrofrequencies associated with the earth's magnetic field at the levels of maximum ionization density in the E and F regions respectively. For the gyrofrequencies we will use the approximate expressions (ref. 2),

$$f_{HE} = 0.87 \left(\frac{6370}{6370 + h_E} \right)^3 [1 + 3 \sin^2 \Phi]^{1/2} \tag{17a}$$

$$f_{HF} = 0.87 \left(\frac{6370}{6370 + h_F} \right)^3 [1 + 3 \sin^2 \Phi]^{1/2} \tag{17b}$$

where f_{HE} and f_{HF} are in MHz, and Φ is the latitude expressed in magnetic coordinates. If ϕ and λ are the respective geographic latitude and longitude, and ϕ_o and λ_o represent the latitude and longitude of the north magnetic pole ($\phi_o \cong 78.3°N$, $\lambda_o \cong 69°W$), then (ref. 2),

$$\sin \Phi = \sin \phi \sin \phi_o + \cos \phi \cdot \cos \phi_o \cdot \cos (\lambda - \lambda_o). \tag{18}$$

We assume that, to calculate deviative absorption for the extraordinary wave, we may use equations (11) and (12), but with $f_{pE}^{(x)}$ and $f_{pF}^{(x)}$ substituted for the ordinary wave penetration frequencies. Otherwise, the calculations for deviative loss take the same form as those for the ordinary wave.

To evaluate L_{dev}, the collision frequency is needed and for this the following approximation will be used,

$$\nu(h) = \exp[12.43 - 0.1773 \cdot (h - 90)] + K \cdot (3.93 \times 10^5) \cdot T^{-3/2} \cdot N(h) \tag{19}$$

Here, $T = T(h)$ is the temperature at height h in degrees Kelvin and K is given by equation (4). The first term on the right side of (19) accounts for collisions between electrons and neutral particles; it is based on table 9.4 of (ref. 3). This term is important in the E region but almost negligible in the F region. The second term in (19) accounts for collisions between electrons and ions and has been taken from equation 4.2.10 of reference 4. This term is relatively

3. Banks, PM, and Kockarts, G, Aeronomy, Part A, Academic Press, 1973
4. Ratcliffe, JA, The Magneto-Ionic Theory and its Applications to the Ionosphere, Cambridge University Press, 1959

small in the E region, but it is the dominant term in the F region. For the heights of interest here, equation (19) provides an adequate approximation to the collision frequency.

For the temperature, T(h), we will use the profile appearing in the 1959 ARDC Model Atmosphere (ref. 5). Throughout the range of interest in h, this temperature profile will be approximated by the polynomial,

$$T(h) = b_0 + b_1 h + b_2 h^2 + b_3 h^3. \tag{20}$$

The coefficients have been determined using a combination of least squares and minimax fits. The results are listed in table 1.

The deviative absorption loss has been incorporated into the Fortran version of the simulator and a revised listing of the program is presented in appendix A. The changes appear mainly in the existing subroutine "ATTEN" and in the new subroutines "DEVIAT" and "TEMP."

A synthetic ionogram has been generated, using the revised computer program. The resulting curves are presented in figure 1 and they should be compared with figure 5 of this report (ref. 1). The delays are identical for the two figures, but the increased attenuation of the high-angle return is readily evident.

Table 1. Coefficients for polynomial approximation of temperature profile

Coefficient	100 km $\leq$ h $<$ 210 km	210 km $\leq$ h $\leq$ 600 km
b_0	1.414×10^{3}	1.424×10^{3}
b_1	-4.428×10^{1}	3.990×10^{-2}
b_2	4.217×10^{-1}	-1.040×10^{-3}
b_3	-1.004×10^{-3}	3.000×10^{-6}

5. Minzer, RA, Champion, KSW, and Pond, HL, The ARDC Model Atmosphere: Air Force Surveys in Geophysics, No. 115, 1959.

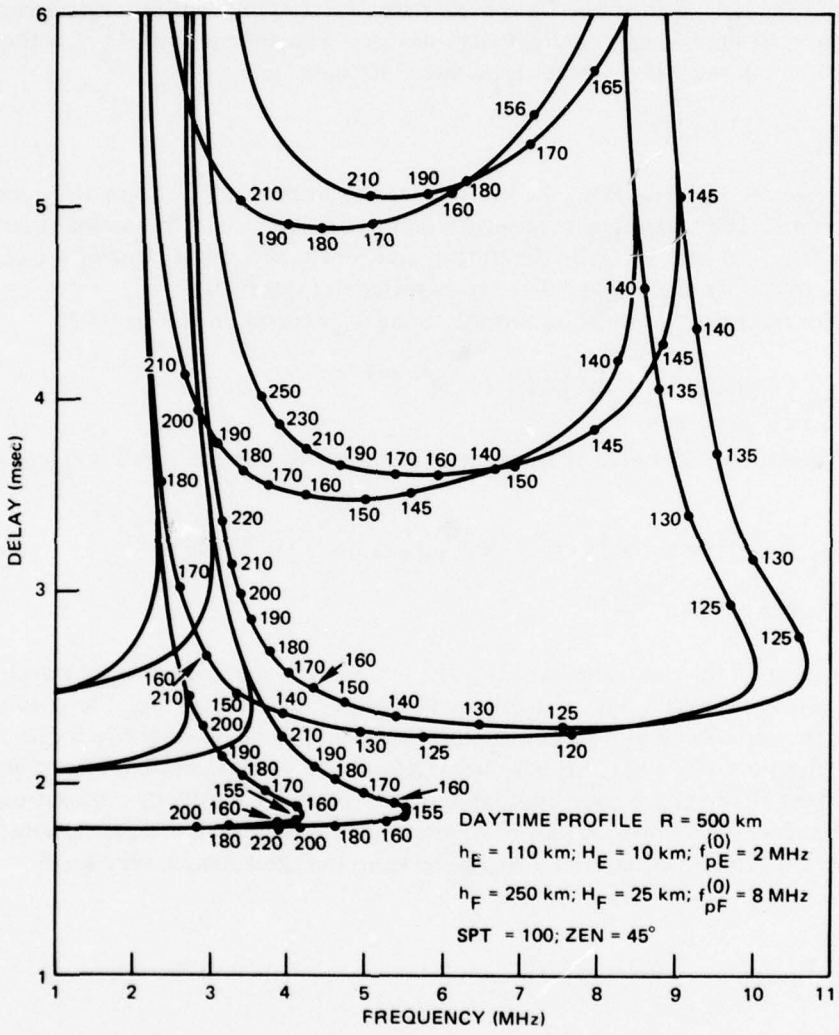

Figure 1. Computed ionosphere returns for one, two, and three hops. (Numbers on curve are attenuation in dB.)

III. GROUNDWAVE ATTENUATION

This section is concerned with the attenuation of a groundwave that has propagated across a rough, curved, lossy ocean surface. Our approach is based on the work of Barrick (ref. 6) and represents an attempt to reduce his expressions to a tractable form for computation. By providing for internal calculation of the groundwave attenuation, the utility of the simulator is increased; since, it is no longer necessary to enter this attenuation as a separate input whenever range, frequency, or sea state change.

Following Barrick, the groundwave loss, L_g, will be written as the sum of two terms. The first term, $L_g^{(1)}$, is the basic transmission loss due to propagation across a smooth, curved, lossy (4 mhos/meter conductivity) surface. The second term, $L_g^{(2)}$, is the additional transmission loss caused by surface roughness. We have

$$L_g = L_g^{(1)} + L_g^{(2)} \tag{21}$$

with all losses in decibels. Both the transmitter and receiver are assumed to be located at the ocean surface. The maximum error incurred as a consequence of this assumption is approximately 3% (ref. 6) and is worth tolerating in view of the attendant simplicity (viz, it is not necessary to specify the heights of the transmitter and receiver).

For the basic transmission loss the following expression will be used,

$$L_g^{(1)} = 20 \log_{10}\left(\frac{2\pi Rf}{0.3}\right) + C_1(f) \cdot R^{C_2(f)} \tag{22}$$

where R is the distance between transmitter and receiver in km, f is the frequency in MHz, and

$$C_1(f) = (1.78 \times 10^{-4}) \cdot f^{2.58} \cdot \exp\left[-(1.40 \times 10^{-8}) \cdot f^5\right] \tag{23}$$

$$C_2(f) = 1.83 \cdot f^{-0.243} \tag{24}$$

The first term on the right side of (22) is the loss the signal experiences by traveling a distance R across a smooth, flat, perfectly conducting surface. The second term is a correction term for the earth's curvature and for a lossy surface; it is based on figure 8 of reference 6. The coefficients $C_1(f)$ and $C_2(f)$ have been determined using a combination of least squares and minimax fits to give a good approximation to Barrick's results throughout the ranges and frequencies of interest. A plot of equation (22) is presented in figure 2 here, together with selected values from Barrick. As can be seen, the agreement is very good.

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6. Battelle Memorial Institute Report, Contract DAAH01-70-C-0312, Theory of Groundwave Propagation Across a Rough Sea at Dekameter Wavelengths, by DE Barrick, 1970.

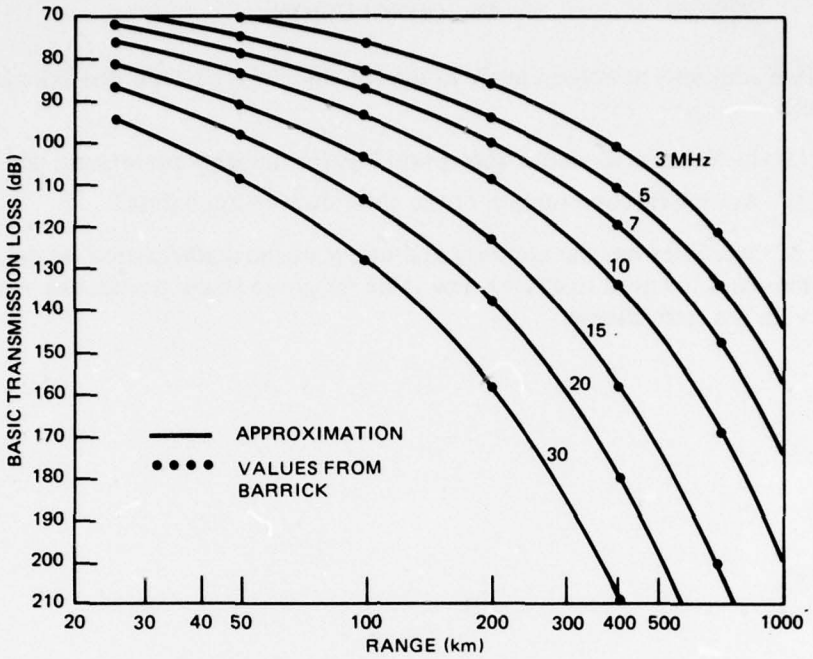

Figure 2. Basic transmission loss for groundwave.

Determination of the additional transmission loss, $L_g^{(2)}$, requires a knowledge of the ocean wave spectrum, which is characterized by specifying the sea state. Two spectra have been considered by Barrick (ref. 6): the Neumann-Pierson spectrum, modified to account for wind direction; and the Phillips spectrum, which is independent of wind direction. The Phillips spectrum was chosen because, as noted by Barrick, it appears to give better agreement with actual observations. Also, the Phillips spectrum results in losses that lie between those obtained for the upwind-downwind and crosswind directions, using the modified Neumann-Pierson spectrum, and it does not require that wind direction be specified as an additional input.

For the additional transmission loss, the dependence on range, frequency, and sea state is complicated and precludes a simple, accurate analytic approximation. However, interpolation can be used to provide good accuracy as well as ease of computation and it is this approach that will be used. The interpolation scheme is linear in both range and frequency, with reference values obtained from figures 25-31 of reference 6. The reference frequencies used are 3, 5, 7, 10, 15, 20 and 30 MHz, while the reference ranges used are 25, 50, 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 km. With these reference points the error attributable to the interpolation is negligible for the ranges and frequencies of interest.

A Fortran version of the calculations necessary to determine the groundwave loss has been incorporated into the simulator; a listing of this program is presented in appendix A of this addendum. The changes consist of a new subroutine "GNDATN" and a statement in the main program that calls this subroutine.

IV. CONCLUSION

Two additions have been made to the HF channel model and the associated simulator. These are:

(1) Inclusion of deviative absorption loss for the skywave returns, and

(2) Automatic computation of the groundwave attenuation.

The first of these improves the accuracy and utility of the mathematical model, while the second eliminates the need to enter a new value for groundwave attenuation whenever range, frequency, or sea state change.

GLOSSARY OF NEW MATHEMATICAL TERMS*

b_j	Coefficients used in the polynomial approximation of the temperature profile
$C_j(f)$	Parameters used in the approximation of $L_g^{(1)}$
L_{dev}	Deviative absorption loss, oblique incidence
$L_{dev}^{(vert)}$	Deviative absorption loss, vertical incidence
L_g	Groundwave loss
$L_g^{(1)}$	Basic transmission loss component of L_g
$L_g^{(2)}$	Additional transmission loss component of L_g
$T = T(h)$	Temperature
$\nu(h)$	Collision frequency
ν_E	Collision frequency at height h_E
ν_F	Collision frequency at height h_F

*This glossary contains only those symbols that are introduced for the first time in this addendum. Other symbols used in the text are listed in the glossary of the report (ref. 1).

APPENDIX A

PROGRAM FOR CALCULATING CHANNEL PARAMETERS

```
      DIMENSION T(48,14),P(4,8),A(3),U(2),TEM(2),CNU(4),F(3)                    0021000010
      COMMON ME,MEM,MF,MFM,TIMF                                                 0021000010
C                                                                               0021000010
C          ***** PROGRAM MODIFIED DECEMBER 1977 *****                          0021000010
C                                                                               0021000010
C          THIS PROGRAM COMPUTES CHANNEL PARAMETERS FROM BASIC INPUTS           0021000010
C                                                                               0021000010
C          GLOSSARY OF MOST IMPORTANT VARIABLES                                 0021000010
C              FC     = CARRIER FREQUENCY (MHZ.)                                0021000010
C              BW     = BANDWIDTH (KHZ.)                                        0021000010
C              XLONG  = LONGITUDE OF TRANSMITTER (DEGREES) + FOR WEST,          0021000010
C                       - FOR EAST)                                             0021000010
C              XLAT   = LATITUDE OF TRANSMITTER (DEGREES) + FOR NORTH,          0021000010
C                       - FOR SOUTH)                                            0021000010
C              R      = DISTANCE BETWEEN TRANSMITTER AND RECEIVER (KM.)         0021000010
C              RAG    = DIRECTION FROM TRANSMITTER TO RECEIVER (DEGREES)        0021000010
C                       MEASURED IN GEOGRAPHIC COORDINATES)                     0021000010
C              RAM    = DIRECTION FROM TRANSMITTER TO RECEIVER (DEGREES)        0021000010
C                       MEASURED IN MAGNETIC COORDINATES)                       0021000010
C              ISEA   = SEA STATE                                               0021000010
C              SPI    = SUNSPOT NUMBER                                          0021000010
C              ZEN    = SOLAR ZENITH ANGLE (DEGREES)                            0021000010
C              TEM(1)= TEMPERATURE AT HEIGHT HFM (DEG. K)                       0021000010
C              TEM(2)= TEMPERATURE AT HEIGHT HFM (DEG. K)                       0021000010
C              TIMF   = TIME OF DAY ('DAY' OR 'NITE')                           0021000010
C              HFM    = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)       0021000010
C              HHE    = THICKNESS OF E REGION (KM.)                             0021000010
C              HFM    = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)       0021000010
C              HHF    = THICKNESS OF F REGION (KM.)                             0021000010
C              FPEO   = PENETRATION FREQ. OF F REGION O-WAVE (MHZ.)             0021000010
C              FPEO   = PENETRATION FREQ. OF F REGION O-WAVE (MHZ.)             0021000010
C              FPEX   = PENETRATION FREQ. OF F REGION X-WAVE (MHZ.)             0021000010
C              FPFX   = PENETRATION FREQ. OF F REGION X-WAVE (MHZ.)             0021000010
C              CNU(1)= ADDITIVE TERM IN EXPONENT OF COLLISION FREQ.             0021000010
C              CNU(2)= MULTIPL. TERM IN EXPONENT OF COLLISION FREQ.             0021000010
C              CNU(3)= SHIFT TERM IN EXPONENT OF COLLISION FREQ.                0021000010
C              CNU(4)= MULTIPL. FACTOR IN SECOND TERM OF COLLISION FREQ.        0021000010
C              ABSMLT= MULTIPLICATIVE CONST. FOR NONDEVIATIVE ABSORPTION        0021000010
C              SPTMLT= SUNSPOT NO. MULTIPLIER FOR NONDEVIATIVE ABSORPTION       0021000010
C              SOLEXP= SOLAR ZEN. ANG. EXPNT. FOR NONDEVIATIVE ABSORPTION       0021000010
C              SHIFTE= E REGION REFERENCE DOPPLER SHIFT (HZ.)                    0021000010
C              EXSHIE= E REGION DOPPLER SHIFT EXPONENT                          0021000010
C              SPRDE  = F REGION REFERENCE DOPPLER SPREAD (HZ.)                  0021000010
C              EXSPRE= F REGION DOPPLER SPREAD EXPONENT                         0021000010
C              RFREQE= E REGION DOPPLER REFERENCE FREQ. (MHZ.)                  0021000010
C              SHIFTF= F REGION REFERENCE DOPPLER SHIFT (HZ.)                   0021000010
C              EXSHIF= F REGION DOPPLER SHIFT EXPONENT                          0021000010
C              SPRDF  = F REGION REFERENCE DOPPLER SPREAD (HZ.)                  0021000010
C              EXSPRF= F REGION DOPPLER SPREAD EXPONENT                         0021000010
C              RFREQF= F REGION DOPPLER REFERENCE FREQ. (MHZ.)                  0021000010
C              ATT    = ATTENUATION (DB.)                                       0021000010
C              ATTDIF= ATTENUATION DIFFERENCE BETWEEN STRONGEST RETURN          0021000010
C                       FROM IONOSPHERE AND WEAKEST RETURN RETAINED             0021000010
C              NPATH  = NO. OF IONOSPHERE RETURNS RETAINED                      0021000010
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C              GDELAY= GROUNDWAVE DELAY (SEC.)                                  C  0021000U10
C              GATTEN= GROUNDWAVE ATTENUATION (DB)                              C  0021000U10
C              IPRINT= PRINT SELECTOR FOR T(I,J) ARRAY ('ALL' OR 'RET')         C  0021000U10
C              NPUNCH= PUNCH SELECTOR. PUNCHES DATA CARDS FOR USE IN            C  0021000U10
C                      SIGNAL ANALYSIS PART OF SIMULATOR IF NPUNCH=1.           C  0021000U10
C                      DOES NOT PUNCH DATA CARDS IF NPUNCH=0.                   C  0021000U10
C                                                                               C  0021000U10
C          ARRAY T(I,J) CONTAINS THE FOLLOWING PARAMETERS                       C  0021000U10
C              I = N: INDEX NUMBER FOR PATH                                     C  0021000U10
C              J = 1: NUMBER OF HOPS                                            C  0021000U10
C                = 2: REGION AND MAGNETOIONIC INDICATOR (ED = E REGION -        C  0021000U10
C                     ORDINARY WAVE; SIMILARLY FOR EX, FO, AND FX)              C  0021000U10
C                = 3: 'HIGH' (FOR HIGH RAY) OR 'LOW' (FOR LOW RAY)              C  0021000U10
C                = 4: SOLUTION INDICATOR (0=NO SOLUTION, 1=SOLUTION)            C  0021000U10
C                = 5: THETA = RAY ANGLE MEASURED FROM VERTICAL (DEGREES)        C  0021000U10
C                = 6: PATH LENGTH (KM.)                                         C  0021000U10
C                = 7: DELAY AT CARRIER FREQUENCY (SEC.)                         C  0021000U10
C                = 8: RECEIVED CARRIER PHASE (CYCLES)                           C  0021000U10
C                = 9: SIGNAL DELAY (SEC.)                                       C  0021000U10
C                =10: AMPLITUDE DISTORTION (SEC/MHZ)                            C  0021000U10
C                =11: PHASE DISTORTION (SEC/MHZ**2)                             C  0021000U10
C                =12: ATTENUATION (DB.)                                         C  0021000U10
C                =13: DOPPLER SHIFT (HZ.)                                       C  0021000U10
C                =14: DOPPLER SPREAD (HZ.)                                      C  0021000U10
C                                                                               C  0021000U10
      PI=3.14159265359                                                          C  0021000U10
      IN='NITE'                                                                 C  0021000510
      PRET='RET'                                                                C  0021000713
C          READ DATA                                                            C  0021000913
      READ/,FC,BW                                                               C  0021000913
                                                                                   FIB IS 0006 LONG
      READ/,XLONG,XLAT                                                          C  0021001310
      READ/,R                                                                   C  0021001U10
      READ/,RAG                                                                 C  0021002510
      READ/,IDEA                                                                C  0021002U10
      READ/,SPT                                                                 C  0021003510
      READ/,ZEN                                                                 C  0021003U10
      READ(5,909)TIME                                                           C  0021004510
      READ/,HENE,HE,FPEO                                                        C  0021004U12
      READ/,HFN,HF,FPFO                                                         C  0021005A10
      READ/,CNU(1),CNU(2),CNU(3),CNU(4)                                         C  0021006610
      READ/,ABSMLT,SPTMLT,SOLEXP                                                C  0021007810
      READ/,SHIFTE,EXSHTE,SPRDF,FXSPRE,RFNEOF                                   C  0021008410
      READ/,SHIFTF,EXSHTF,SPRDF,FXSPRF,RFREOF                                   C  0021009410
      READ/,AITDIF                                                              C  002100A410
      READ(5,909)IPRINT                                                         C  002100A610
      READ/,NPUNCH                                                              C  002100B312
C          END READ DATA                                                        C  002100BU10
C          COMPUTE PENETRATION FREQUENCIES FOR EXTRAORDINARY WAVES              C  002100BU10
      CALL GETOMA(XLAT,XLONG,XLATM,XLONGM)                                      C  002100BU10
      SINPHI=SIN((PI/180.)*XLATM)                                               C  002100BU14
      XMLAT=.87*SQRT(1.+3.*(SINPHI**2))                                         C  002100CU11
      FNEX=XMLAT*((6370./(6370.+HEN))**3)                                       C  002100C415
      FNFX=XMLAT*((6370./(6370.+HFN))**3)                                       C  002100C810
      FPEX=.5*FNEX+SQRT((FPEO**2)+(.25*(FNEX**2)))                              C  002100CU14
      FPFX=.5*FNFX+SQRT((FPFO**2)+(.25*(FNFX**2)))                              C  002100D415
C          END COMPUTATION OF PENETRATION FREQS. FOR EXTRAORDINARY WAVES        C  002100D715
C          COMPUTE BEARING OF RECEIVER IN MAGNETIC COORDINATES                  C  002100D715
      CALL BNGMAG(XLAT,XLONG,R,RAG,RAM)                                         C  002100D715
C          END COMPUTATION OF RECEIVER BEARING                                  C  002100DU10
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C           COMPUTE TEMPERATURES AT HEM AND HFM                          C 002100D810
      CALL TEMP(HEM,TEM(1))                                              C 002100D810
      CALL TEMP(HFM,TEM(2))                                              C 002100DC10
C           END COMPUTATION OF TEMPERATURES                              C 002100DF10
C           COMPUTE GROUNDWAVE DELAY                                     C 002100DF10
      GDELAY=R/(3.E+05)                                                  C 002100DF10
C           END COMPUTATION OF GROUNDWAVE DELAY                          C 002100E110
C           COMPUTE GROUNDWAVE ATTENUATION                               C 002100E110
      CALL GNDATN(FC,ISEA,R,GATTEN)                                      C 002100E110
C           END COMPUTATION OF GROUNDWAVE ATTENUATION                    C 002100E412
      WRITE(6,910)                                                       C 002100E412
                                                                           FIB IS 0006 LONG
      WRITE(6,911)                                                       C 002100E812
      WRITE(6,912)FC,BW                                                  C 002100EC12
      WRITE(6,913)                                                       C 002100F012
      WRITE(6,915)XLONG                                                  C 002100F812
      WRITE(6,916)XLAT                                                   C 002100FC12
      WRITE(6,917)R                                                      C 0021010812
      WRITE(6,918)BAG                                                    C 0021010C12
      WRITE(6,919)                                                       C 0021011012
      WRITE(6,920)                                                       C 0021011812
      WRITE(6,921)ISEA                                                   C 0021011C12
      WRITE(6,922)                                                       C 0021012012
      WRITE(6,923)SPT                                                    C 0021012812
      IF(TIME.IS.TN)GO TO 9                                              C 0021012C12
      WRITE(6,932)ZEN                                                    C 0021013010
      GOTO10                                                             C 0021013812
 9    WRITE(6,933)                                                       C 0021013815
 10   IF(TIME.IS.TN)GO TO 11                                             C 0021013812
      WRITE(6,924)                                                       C 0021013D10
      GOTO12                                                             C 0021014112
 11   WRITE(6,925)                                                       C 0021014115
 12   WRITE(6,926)HEM                                                    C 0021014812
      SE=2.*HE                                                           C 0021014D12
      WRITE(6,927)SE                                                     C 0021014D15
      WRITE(6,928)FMED                                                   C 0021015512
      WRITE(6,930)FMEX                                                   C 0021015C12
      WRITE(6,960)HEM,TEM(1)                                             C 0021016812
      WRITE(6,929)HFM                                                    C 0021016C12
      SF=2.*HF                                                           C 0021017812
      WRITE(6,927)SF                                                     C 0021017810
      WRITE(6,928)FMFD                                                   C 0021017812
      WRITE(6,930)FMFX                                                   C 0021018212
      WRITE(6,960)HFM,TEM(2)                                             C 0021018912
      WRITE(6,961)                                                       C 0021019212
      WRITE(6,962)CNU(1),CNU(2),CNU(3)                                   C 0021019612
      WRITE(6,963)CNU(4)                                                 C 002101A012
      WRITE(6,953)                                                       C 002101A712
      WRITE(6,954)ABSMIT,SPTHLT,SULEXP                                   C 002101AB12
      WRITE(6,945)                                                       C 002101B512
      WRITE(6,946)SMIFTE,EXSHTF,SPRDE,EXSPRE,RFREQE                      C 002101B912
      WRITE(6,947)SMIFTF,EXSHTF,SPRDF,EXSPRF,RFREQF                      C 002101C612
      WRITE(6,900)                                                       C 002101D312
      WRITE(6,934)                                                       C 002101D712
      WRITE(6,900)                                                       C 002101DB12
      WRITE(6,935)GDELAY,GATTEN                                          C 002101DF12
      WRITE(6,936)                                                       C 002101E712
C           DO 60 COMPUTES THE ARRAY T(I,J)                              C 002101EB12
      DO60NHOP=1,6                                                       C 002101ED12
      XNHOP=FLOAT(NHOP)                                                  C 002101EC10
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      RH=H/XNHOP                                                        C  002:01E6:5
      NNHOP=8*(NHOP-1)                                                  C  002:01EE:1
      DO35I=1,8                                                         C  002:01F0:0
      II=I+NNHOP                                                        C  002:01F1:0
      T(II,1)=NHOP                                                      C  002:01F2:3
   35 CONTINUE                                                          C  002:01F3:5
      I=1+NNHOP                                                         C  002:01F6:0
C          ASSIGN LABELS TO EACH TRANSMISSION MODE                      C  002:01F7:2
      T(I,2)='EO'                                                       C  002:01F7:2
      T(I,3)='LOW '                                                     C  002:01FA:1
      I=I+1                                                             C  002:01FD:1
      T(I,2)='EO'                                                       C  002:01FE:3
      T(I,3)='HIGH'                                                     C  002:0201:1
      I=I+1                                                             C  002:0204:1
      T(I,2)='FO'                                                       C  002:0205:3
      T(I,3)='LOW '                                                     C  002:0208:1
      I=I+1                                                             C  002:020B:1
      T(I,2)='FO'                                                       C  002:020C:3
      T(I,3)='HIGH'                                                     C  002:020F:1
      I=I+1                                                             C  002:0212:1
      T(I,2)='EX'                                                       C  002:0213:3
      T(I,3)='LOW '                                                     C  002:0216:1
      I=I+1                                                             C  002:0219:1
      T(I,2)='EX'                                                       C  002:021A:3
      T(I,3)='HIGH'                                                     C  002:021D:1
      I=I+1                                                             C  002:0220:1
      T(I,2)='FX'                                                       C  002:0221:3
      T(I,3)='LOW '                                                     C  002:0224:1
      I=I+1                                                             C  002:0227:1
      T(I,2)='FX'                                                       C  002:0228:3
      T(I,3)='HIGH'                                                     C  002:022B:1
C          END LABEL ASSIGNMENT                                         C  002:022E:1
C          NMAG = 1 FOR ORDINARY WAVE; NMAG = 2 FOR EXTRAORDINARY WAVE  C  002:022E:1
      DO90NMAG=1,2                                                      C  002:022E:1
      IF(NMAG-1)36,36,37                                                C  002:022F:0
C          SUBROUTINE 'PATH' RETURNS ARRAY P(I,J) CONTAINING SIGNAL     C  002:0230:4
C          PATH LENGTH, DELAY AND DELAY DERIVATIVES                     C  002:0230:4
   36 CALL PATH(RH,FPEO,FPFO,FC,P)                                      C  002:0230:4
      GOTO38                                                            C  002:0234:0
   37 CALL PATH(RH,FPEX,FPFX,FC,P)                                      C  002:0234:3
   38 DO80I=1,4                                                         C  002:0237:5
      II=I+4*(NMAG-1)+NNHOP                                             C  002:0239:0
      T(I,4)=P(I,1)                                                     C  002:023B:5
      T(II,5)=(180./PI)*ARCOS(P(I,3))*P(I,1)                            C  002:023E:0
      T(II,6)=XNHOP*P(I,4)                                              C  002:0243:3
      T(II,7)=P(I,5)*XNHOP                                              C  002:0246:4
      T(II,8)=FC*P(I,5)*XNHOP*(1.E+06)                                  C  002:024A:0
      INT=T(II,8)                                                       C  002:024F:2
      T(II,8)=T(II,8)-FLOAT(INT)                                        C  002:0250:0
      T(II,9)=(P(I,5)+FC*P(I,6))*XNHOP                                  C  002:0252:3
      T(II,10)=(P(I,6)+.5*FC*P(I,7))*XNHOP                              C  002:0257:4
      T(II,11)=((.5*P(I,7))+((FC*P(I,8))/6.))*XNHOP                     C  002:025E:4
C          COMPUTE ATTENUATION                                          C  002:0266:2
      XINU=P(I,1)*(1.E*08)                                              C  002:0266:2
      IF(XINU)21,21,20                                                  C  002:0269:4
   20 TH=T(II,5)                                                        C  002:026A:3
      DIST=T(II,6)                                                      C  002:026E:1
      XMAG=3.**2.*FLOAT(NMAG)                                           C  002:026D:5
      A(1)=ABSMLT                                                       C  002:026F:4
      A(2)=SPIMLT                                                       C  002:0270:5
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      A(3)=SOLEXP                                                                C  002:027A10
      G(1)=XLATM                                                                 C  002:027B12
      G(2)=RAM                                                                   C  002:027C13
      F(1)=FC                                                                    C  002:027D14
      IF(NMAG-1)41,41,42                                                         C  002:027E15
   41 F(2)=FPLO                                                                  C  002:027F10
      F(3)=FPLO                                                                  C  002:0280 1
      GUTO43                                                                     C  002:0281 3
   42 F(2)=FPLX                                                                  C  002:0282 0
      F(3)=FPLX                                                                  C  002:0283 1
   43 CALL ATTEN(G,TM,SPT,ZEN,TFM,CNO,DIST,NMOP,F,XMAG,A,ATT)                    C  002:0284 3
      T(I,12)=ATT                                                                C  002:0285 0
      GUTO22                                                                     C  002:0286 0
   21 T(I,12)=0.                                                                 C  002:0287 3
C          END COMPUTATION OF ATTENUATION                                        C  002:0288 2
C          COMPUTE DOPPLER SHIFTS AND SPREADS                                    C  002:0289 2
   22 XIND=FLOAT(I)**2.5                                                         C  002:028A 2
      IF(XIND)23,23,24                                                           C  002:028B 4
   23 T(I,13)=XNMOP*SHIFTE*((FC/REFREQE)**EXSHTE)*P(I,1)                         C  002:028C 3
      T(I,14)=SQRT(XNMOP)*SPRDE*((FC/REFREQE)**EXSPRE)*P(I,1)                    C  002:028D 3
      GUTO25                                                                     C  002:028E 1
   24 T(I,13)=XNMOP*SHIFTF*((FC/REFREQF)**EXSHTF)*P(I,1)                         C  002:028F 4
      T(I,14)=SQRT(XNMOP)*SPRDF*((FC/REFREQF)**EXSPRF)*P(I,1)                    C  002:0290 4
   25 CONTINUE                                                                   C  002:0291 2
C          END COMPUTATION OF SHIFTS AND SPREADS                                 C  002:0292 2
   40 CONTINUE                                                                   C  002:0293 2
   50 CONTINUE                                                                   C  002:0294 3
   60 CONTINUE                                                                   C  002:0295 4
C          DO 70 DETERMINES MINIMUM (NONZERO) ATTENUATION                        C  002:0296 5
      ATTMIN=1.E+05                                                              C  002:0297 5
      ATTMAX=0.                                                                  C  002:0298 3
      DO701=1,48                                                                 C  002:0299 1
      IF(T(I,12))70,70,61                                                        C  002:029A 0
   61 ATTMIN=AMIN1(T(I,12),ATTMIN)                                               C  002:029B 1
      ATTMAX=AMAX1(T(I,12),ATTMAX)                                               C  002:029C 0
   70 CONTINUE                                                                   C  002:029D 5
      IF(ATTMAX)71,71,72                                                         C  002:029E 0
   71 WRITE(6,950)                                                               C  002:029F 1
      NPATH=0                                                                    C  002:02C0 2
      GUTO120                                                                    C  002:02C1 0
   72 WRITE(6,938)                                                               C  002:02C2 3
      WRITE(6,939)                                                               C  002:02C3 2
      WRITE(6,940)                                                               C  002:02C4 2
      IF(IPRINT.IS.PHET)GUTO101                                                  C  002:02C5 2
C          DO 100 PRINTS THE COMPLETE ARRAY T(I,J)                               C  002:02C6 4
      DO100I=1,48                                                                C  002:02C7 4
      IN=I(I,1)+1.E-05                                                           C  002:02D8 0
      WRITE(6,941)IN,T(I,2),T(I,3),T(I,4),T(I,5),T(I,6),T(I,7),T(I,8),T(         C  002:02D9 5
     1I,9),T(I,10),T(I,11),T(I,12),T(I,13),T(I,14)                               C  002:02EA 1
  100 CONTINUE                                                                   C  002:02FB 2
C          DO 110 DETERMINES NPATH AND MODIFIES ARRAY T(I,J) SO THAT              C  002:02FC 3
C          IT CONTAINS ONLY THE DESIRED RETURNS                                  C  002:02FD 3
  101 ATTLIM=ATTMIN+ATTDIF                                                       C  002:02FE 3
      NPATH=0                                                                    C  002:02FF 5
      DO110I=1,48                                                                C  002:0300 3
      IF(T(I,12))110,110,102                                                     C  002:0301 0
  102 IF(T(I,12)-ATTLIM)103,103,110                                              C  002:0302 1
  103 NPATH=NPATH+1                                                              C  002:0303 3
      DO105J=1,14                                                                C  002:0304 5
      T(NPATH,J)=T(I,J)                                                          C  002:0305 0
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 105  CONTINUE                                                          C  0021030C14
 110  CONTINUE                                                          C  0021030C15
      IF((IPRINT.LT.5.PRLT)GOTO114                                      C  0021031110
      GOTO115                                                           C  0021031212
C          DO 115 PRINTS THE MODIFIED ARRAY T(I,J)                     C  0021031215
 114  DO115I=1,NPATH                                                    C  0021031215
      IN=I(I,1)+1.E-05                                                  C  0021031410
      WRITE(6,951)IN,T(I,4),T(I,5),T(I,6),T(I,7),T(I,8),T(I,9),T(       C  0021031715
     1I,10),T(I,11),T(I,12),T(I,13),T(I,14)                             C  0021032012
 115  CONTINUE                                                          C  0021033612
      WRITE(6,900)                                                      C  0021033E13
      WRITE(6,952)ALTDIF                                                C  0021034212
 120  CONTINUE                                                          C  0021034912
C          PUNCH DATA CARDS FOR USE IN SIGNAL ANALYSIS PART OF SIMULATOR C  0021034912
C          IF NPUNCH=1 (PUNCHES MODIFIED ARRAY T(I,J))                 C  0021034912
      IF(NPUNCH-1)140,121,140                                           C  0021034912
 121  PUNCH/,TC,RW,M,NPATH                                              C  0021034A13
                                                                          FIB IS 0006 LONG
      PUNCH 909,TIME                                                    C  0021035612
      PUNCH/,GDELAY,GAITEN                                              C  0021035D12
      DO130I=1,NPATH                                                    C  0021036512
      PUNCH 955,(T(I,J),J=1,7)                                          C  0021036610
      PUNCH 956,(T(I,J),J=8,11)                                         C  0021037512
      PUNCH 957,(T(I,J),J=12,14)                                        C  0021038012
 130  CONTINUE                                                          C  0021038D12
 140  CONTINUE                                                          C  0021038F13
C          END PUNCH DATA CARDS                                        C  0021038F13
 900  FORMAT(1X)                                                        C  0021039F13
 901  FORMAT(1X,/)                                                      C  0021038F13
 902  FORMAT(1X,//)                                                     C  0021038F13
 903  FORMAT(1X,///)                                                    C  0021038F13
 904  FORMAT(1X,////)                                                   C  0021038F13
 909  FORMAT(A6)                                                        C  0021038F13
 910  FORMAT(46X,'SUMMARY OF TRANSMISSION PARAMETERS'///)               C  0021038F13
 911  FORMAT(1X,'SIGNAL PARAMETERS'/)                                   C  0021038F13
 912  FORMAT(9X,'CARRIER FREQ. =',F7.3,' MHZ.    BANDWIDTH =',F7.2,' KHZ C  0021038F13
     1.'/)                                                              C  0021038F13
 913  FORMAT(1X,'TRANSMITTER/RECEIVER PARAMETERS'/)                     C  0021038F13
 915  FORMAT(9X,'LOCATION OF TRANSMITTER: LONGITUDE = ',F7.2,' DEGREES ( C  0021038F13
     1+ FOR WEST, - FOR EAST)')                                         C  0021038F13
 916  FORMAT(34X,'LATITUDE  = ',F7.2,' DEGREES (+ FOR NORTH, - FOR SOUTH C  0021038F13
     1)')                                                               C  0021038F13
 917  FORMAT(9X,'DISTANCE BETWEEN TRANSMITTER AND RECEIVER =',F8.2,' KM. C  0021038F13
     1')                                                                C  0021038F13
 918  FORMAT(9X,'DIRECTION FROM TRANSMITTER TO RECEIVER =',F6.2,' DEGREE C  0021038F13
     1S (MEASURED FROM TRUE NORTH)')                                    C  0021038F13
 919  FORMAT(9X,'TRANSMITTER ANTENNA PATTERN = (3/2)*(SIN(THETA)**2)')  C  0021038F13
 920  FORMAT(9X,'RECEIVER ANTENNA PATTERN = (3/2)*(SIN(THETA)**2)')     C  0021038F13
 921  FORMAT(9X,'SEA STATE =',I2/)                                      C  0021038F13
 922  FORMAT(1X,'IONOSPHERE PARAMETERS'/)                               C  0021038F13
 923  FORMAT(9X,'SUNSPOT NUMBER = ',F7.2)                               C  0021038F13
 924  FORMAT(9X,'DAYTIME ELECTRON DENSITY PROFILE')                     C  0021038F13
 925  FORMAT(9X,'NIGHTTIME ELECTRON DENSITY PROFILE')                   C  0021038F13
 926  FORMAT(15X,'F REGION: HEIGHT OF MAX. ELECTRON DENSITY =',F7.2,' KM C  0021038F13
     1.')                                                               C  0021038F13
 927  FORMAT(25X,'SEMITHICKNESS OF PARABOLA =',F7.2,' KM.')             C  0021038F13
 928  FORMAT(25X,'PENETRATION FREQUENCY, ORDINARY WAVE =',F7.3,' MHZ.') C  0021038F13
 929  FORMAT(15X,'F REGION: HEIGHT OF MAX. ELECTRON DENSITY =',F7.2,' KM C  0021038F13
     1.')                                                               C  0021038F13
 930  FORMAT(25X,'PENETRATION FREQUENCY, EXTRAORDINARY WAVE =',F7.3,' MH C  0021038F13
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     1Z,')                                                                  C  0021038F13
 932 FORMAT(9X,'SOLAR ZENITH ANGLE =',F7.2,' DEGREES')                      C  0021038F13
 933 FORMAT(9X,'SOLAR ZENITH ANGLE = NOT APPLICABLE TO NIGHTTIME TRANSM     C  0021038F13
     1ISSION')                                                              C  0021038F13
 934 FORMAT(1X,'COMPUTED CHANNEL PARAMETERS'/)                              C  0021038F13
 935 FORMAT(1X,'GROUNDWAVE:  DELAY = ',1PE10.3,' SEC.    ATTENUATION =     C  0021038F13
     1',F10.3,' DB.')                                                       C  0021038F13
 936 FORMAT(1X,'IONOSPHERE RETURNS:'/)                                      C  0021038F13
 938 FORMAT( 3X,'MODE',3X,'SOLUTION',3X,'RAY ANGLE',3X,'PATH',4X,'CARRI     C  0021038F13
     1ER',4X,'CARRIER',3X,'  SIGNAL  ',1X,'AMPLITUDE',4X,'PHASE',5X,'ATT    C  0021038F13
     2ENUATION',2X,'DOPPLER',4X,'DOPPLER')                                  C  0021038F13
 939 FORMAT(10X,'INDICATOR',2X,'(DEGREES)',2X,'LENGTH',4X,'DELAY',6X,'P     C  0021038F13
     1HASE',6X,'DELAY',3X,'DISTORTION',1X,' DISTORTION',5X,'(DB)', 7X,'S    C  0021038F13
     2HIFT',5X,'SPREAD')                                                    C  0021038F13
 940 FORMAT( 9X,'(0=NO SOLN)',13X,'(KM)',5X,'(SEC)',4X,'(CYCLES)',5X,'(     C  0021038F13
     1SEC)',4X,'(SEC/MHZ)',1X,'(SEC/MHZ**2)',15X,'(HZ)', 7X,'(HZ)'/)       C  0021038F13
 941 FORMAT(1X,I1,A2,1X,A4,4X,F3.1,7X,F5.2,1X,F9.2,1X,1PE10.3,1X,E10.3,     C  0021038F13
     11X,E10.3,1X,E10.3,2X,E10.3,2X,E10.3,1X,E10.3,1X,E10.3)                C  0021038F13
 945 FORMAT(9X,'DOPPLER REFERENCE VALUES')                                  C  0021038F13
 946 FORMAT(15X,'F REGION: SHIFT =',F8.4,' HZ,',1X,'SHIFT EXP. =',F6.3,     C  0021038F13
     1' SPREAD =',F8.4,' HZ,',1X,'SPREAD EXP. =',F6.3,' REF. FREQ. =',      C  0021038F13
     2F7.3,' MHZ.')                                                         C  0021038F13
 947 FORMAT(15X,'F REGION: SHIFT =',F8.4,' HZ,',1X,'SHIFT EXP. =',F6.3,     C  0021038F13
     1' SPREAD =',F8.4,' HZ,',1X,'SPREAD EXP. =',F6.3,' REF. FREQ. =',      C  0021038F13
     2F7.3,' MHZ.')                                                         C  0021038F13
 950 FORMAT(22X,'***** THERE ARE NO RETURNS FROM THE IONOSPHERE FOR THI     C  0021038F13
     1S FREQUENCY AND RANGE *****')                                         C  0021038F13
 951 FORMAT(1X,I1,A2,1X,A4,4X,'NA',8X,F5.2,1X,F9.2,1X,1PE10.3,1X,E10.3,     C  0021038F13
     11X,E10.3,1X,E10.3,2X,E10.3,2X,E10.3,1X,E10.3,1X,E10.3)                C  0021038F13
 952 FORMAT(9X,'ALL IONOSPHERE RETURNS WHOSE ATTENUATION IS GREATER THA     C  0021038F13
     1N ',F7.2,' DB. ABOVE THE MINIMUM ATTENUATION ARE IGNORED')            C  0021038F13
 953 FORMAT(9X,'NONDEVIATIVE ABSORPTION CONSTANTS')                         C  0021038F13
 954 FORMAT(15X,'MULTIPLICATIVE CONSTANT =',F8.2,', SUNSPOT NUMBER MULT     C  0021038F13
     1IPLIER =',F9.6,', SOLAR ZENITH ANGLE EXPONENT =',F6.3)                C  0021038F13
 955 FORMAT(11,A2,A4,4E10.9)                                                C  0021038F13
 956 FORMAT(4E16.9)                                                         C  0021038F13
 957 FORMAT(3E16.9)                                                         C  0021038F13
 960 FORMAT(25X,'TEMPERATURE AT',F7.2,' KM. = ',F7.2,' DEG. K')             C  0021038F13
 961 FORMAT(9X,'CONSTANTS USED IN DETERMINATION OF COLLISION FREQUENCIE     C  0021038F13
     1S')                                                                   C  0021038F13
 962 FORMAT(15X,'EXPONENT OF FIRST TERM: ADDITIVE CONST. =',F8.4,', MUL     C  0021038F13
     1TIPLICATIVE CONST. =',F8.4,', SHIFT CONST. =',F8.4)                   C  0021038F13
 963 FORMAT(15X,'MULTIPLICATIVE CONST. OF SECOND TERM =',1PE12.4)           C  0021038F13
                                                                            C  0021038F13
     STOP                                                                   C  0021038F13
     END                                                                    C  0021039002
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      SUBROUTINE BNGMAG(PHIT,XLAMT,R,ANGLEG,ANGLEM)                          C  00B1000010
                                                                             C  00B1000010
C          SUBROUTINE COMPUTES BEARING OF THE RECEIVER FROM THE             C  00B1000010
C          TRANSMITTER IN MAGNETIC COORDINATES                              C  00B1000010
C              PHIT   = GEOGRAPHIC LATITUDE OF TRANSMITTER (DEGREES)        C  00B1000010
C              XLAMT  = GEOGRAPHIC LONGITUDE OF TRANSMITTER (DEGREES)       C  00B1000010
C              R      = DISTANCE BETWEEN TRANSMITTER AND RECEIVER (KM.)     C  00B1000010
C              ANGLEG= BEARING OF RECEIVER IN GEOGRAPHIC COORD.(DEGREES)    C  00B1000010
C              ANGLEM= BEARING OF RECEIVER IN MAGNETIC COORD. (DEGREES)     C  00B1000010
                                                                             C  00B1000010
      PI=3.14159265359                                                       C  00B1000010
      CC=PI/180.                                                             C  00B1000510
      GG=ANGLEG/180.                                                         C  00B1000610
      IF(GG)6,5,6                                                            C  00B1000712
 5    PHIR=PHIT+(R/(CC*6370.))                                               C  00B1000811
      GOTO8                                                                  C  00B1000A14
 6    IF(GG-1.)10,7,10                                                       C  00B1000B11
 7    PHIR=PHIT-(R/(CC*6370.))                                               C  00B1000C12
 8    XLAMR=XLAMT                                                            C  00B1000C15
      GOTO20                                                                 C  00B1000F14
 10   A=CC*(90.-PHIT)                                                        C  00B1001011
      B=R/6370.                                                              C  00B1001210
      G=(CC*ANGLEG)/2.                                                       C  00B1001313
      D1=(A-B)/2.                                                            C  00B1001512
      S1=(A+B)/2.                                                            C  00B1001711
      W1=SIN(D1)/(TAN(G)*SIN(S1))                                            C  00B1001910
      W2=COS(D1)/(TAN(G)*COS(S1))                                            C  00B1001C15
      Z1=ATAN(W1)                                                            C  00B1002014
      Z2=ATAN(W2)                                                            C  00B1002211
      W3=(TAN(S1)*COS(Z2))/COS(Z1)                                           C  00B1002414
      C=2.*ATAN(W3)                                                          C  00B1002713
      PHIR=90.-(C/CC)                                                        C  00B1002913
      XLAMR=XLAMT+((Z2-Z1)/CC)                                               C  00B1002B12
 20   CALL GEIOMA(PHIT,XLAMT,PHITM,XLAMTM)                                   C  00B1002D14
      CALL GEIOMA(PHIR,XLAMR,PHIRM,XLAMRM)                                   C  00B1003012
      D2=(CC/2.)*(PHIRM-PHITM)                                               C  00B1003210
      S2=(CC/2.)*(PHIRM+PHITM)                                               C  00B1003512
      D=(CC/2.)*(XLAMTM-XLAMRM)                                              C  00B1003714
      IF(D)55,50,55                                                          C  00B1003A10
 50   IF(PHIRM-PHITM)51,52,52                                                C  00B1003A15
 51   ANGLEM=180.                                                            C  00B1003C11
      GOTO100                                                                C  00B1003D10
 52   ANGLEM=0.                                                              C  00B1003D13
      GOTO100                                                                C  00B1003E11
 55   W4=SIN(D2)/(TAN(D)*COS(S2))                                            C  00B1003E14
      W5=COS(D2)/(TAN(D)*SIN(S2))                                            C  00B1004213
      Z4=ATAN(W4)                                                            C  00B1004412
      Z5=ATAN(W5)                                                            C  00B1004715
      ANGLEM=((Z5-Z4)/CC)                                                    C  00B1004912
 100  RETURN                                                                 C  00B1004A15
      END                                                                    C  00B1004B12
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      SUBROUTINE ATTEN(G,TH,SPT,ZEN,TEM,CNU,DIST,NHOP,F,XMAG,A,ATT)                C 0111000010
      DIMENSION G(2),TEM(2),CNU(4),F(3),A(3),XNU(2)                               C 0111000010
      COMMON HE,HEM,HF,HFM,TIME                                                   C 0111000010
C                                                                                 C 0111000010
C          SUBROUTINE COMPUTES TOTAL ATTENUATION OF IONOSPHERE RETURNS            C 0111000010
C                                                                                 C 0111000010
C          ***** PROGRAM MODIFIED DECEMBER 1977 *****                             C 0111000010
C                                                                                 C 0111000010
C               HHE    = THICKNESS OF E REGION (KM.)                              C 0111000010
C               HEM    = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)        C 0111000010
C               F(2)   = PENETRATION FREQUENCY OF E REGION (MHZ.)                 C 0111000010
C               HHF    = THICKNESS OF F REGION (KM.)                              C 0111000010
C               HFM    = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)        C 0111000010
C               F(3)   = PENETRATION FREQUENCY OF F REGION (MHZ.)                 C 0111000010
C               G(1)   = MAGNETIC LATITUDE (DEGREES)                              C 0111000010
C               G(2)   = BEARING OF RECEIVER IN MAGNETIC COORD. (DEGREES)         C 0111000010
C               TH     = RAY ANGLE MEASURED FROM VERTICAL (DEGREES)               C 0111000010
C               X      = COS(TH)                                                  C 0111000010
C               SPT    = SUNSPOT NUMBER                                           C 0111000010
C               ZEN    = SOLAR ZENITH ANGLE (DEGREES)                             C 0111000010
C               TEM(1)= TEMPERATURE AT HEIGHT HEM (DEG. K)                        C 0111000010
C               TEM(2)= TEMPERATURE AT HEIGHT HFM (DEG. K)                        C 0111000010
C               TIME   = TIME OF DAY ('DAY' OR 'NITE')                            C 0111000010
C               NHOP   = NUMBER OF HOPS                                           C 0111000010
C               DIST   = TOTAL SIGNAL PATH LENGTH (KM.)                           C 0111000010
C               F(1)   = CARRIER FREQUENCY (MHZ.)                                 C 0111000010
C               XMAG   = INDICATOR (+1 FOR O-WAVE, -1 FOR X-WAVE)                 C 0111000010
C               A(1)   = MULTIPLICATIVE CONST. FOR NONDEVIATIVE ABSORPTION        C 0111000010
C               A(2)   = SUNSPOT NO. MULTIPLIER FOR NONDEVIATVE ABSORPTION        C 0111000010
C               A(3)   = SOLAR ZEN. ANG. EXPNT. FOR NONDEVIATVE ABSORPTION        C 0111000010
C               CNU(1)= ADDITIVE TERM IN EXPONENT OF COLLISION FREQ.              C 0111000010
C               CNU(2)= MULTIPL. TERM IN EXPONENT OF COLLISION FREQ.              C 0111000010
C               CNU(3)= SHIFT TERM IN EXPONENT OF COLLISION FREQ.                 C 0111000010
C               CNU(4)= MULTIPL. FACTOR IN SECOND TERM OF COLLISION FREQ.         C 0111000010
C               XNU(1)= COLLISION FREQ. AT HEIGHT HEM (MHZ.)                      C 0111000010
C               XNU(2)= COLLISION FREQ. AT HEIGHT HFM (MHZ.)                      C 0111000010
C               DBNOND= NONDEVIATIVE ABSORPTION (DB.)                             C 0111000010
C               DBDEV  = DEVIATIVE ABSORPTION (DB.)                               C 0111000010
C               DBR2   = SPREADING (1/R**2) LOSS (DB.)                            C 0111000010
C               DBANT  = ANTENNA PATTERN LOSS (DB.)                               C 0111000010
C               ATT    = TOTAL SIGNAL ATTENUATION (DB.)                           C 0111000010
C                                                                                 C 0111000010
      PI=3.14159265359                                                            C 0111000010
      CC=PI/180.                                                                  C 0111000510
      TN='NITE'                                                                   C 0111000610
      XTH=CC*TH                                                                   C 0111000813
      X=COS(XTH)                                                                  C 0111000915
C          COMPUTE NONDEVIATIVE ABSORPTION                                        C 0111000812
      IF(TIME.IS.TN)GO TO 9                                                       C 0111000812
      ANGIND=ATAN(-2.*TAN(CC*G(1)))                                               C 0111000810
      XRAM=CC*G(2)                                                                C 0111001014
      XA=SIN(XTH)*COS(XRAM)*COS(ANGIND)                                           C 0111001214
      XB=COS(XTH)*SIN(ANGIND)                                                     C 0111001613
      XI=ABS(XA+XB)                                                               C 0111001911
      XR=ABS(XA-XB)                                                               C 0111001A15
      FM=.87*SQRT(1.+3.*((SIN(CC*G(1)))**2))*((6370./6440.)**3)                   C 0111001613
      B=(A(1)*(1.+A(2)*SPT)*((COS(CC*ZEN))**A(3)))/COS(XTH)                       C 0111002412
      DBI=B/((F(1)+XMAG*FM*XI)**2)                                                C 0111002613
      DBR=B/((F(1)+XMAG*FM*XR)**2)                                                C 0111002F14
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      DBNUND=FLOAT(NHOP)*(DBI+DBR)                                          C  0111003311
      GOTO10                                                                C  0111003310
    9 DBNUND=0.                                                             C  0111003313
   10 CONTINUE                                                              C  0111003611
C          END COMPUTATION OF NONDEVIATIVE ABSORPTION                       C  0111003611
C          COMPUTE DEVIATIVE ABSORPTION                                     C  0111003611
      XNU(1)=EXP(CNU(1)-CNU(2)*(HFM-CNU(3)))+(CNU(4)*(F(2)**2))/(TEM(1)*    C  0111003611
     1*1.5)                                                                 C  0111003E14
      XNU(2)=EXP(CNU(1)-CNU(2)*(HFM-CNU(3)))+(CNU(4)*(F(3)**2))/(TEM(2)*    C  0111004113
     1*1.5)                                                                 C  0111004A14
      CALL DEVIAT(F,X,XNU,DBDEV)                                            C  0111004D13
      DBDEV=FLOAT(NHOP)*DBDEV                                               C  0111005014
C          END COMPUTATION OF DEVIATIVE ABSORPTION                          C  0111005210
C          COMPUTE 1/R**2 LOSS                                              C  0111005210
      DBR2=20.*ALOG10((4.*PI*DIST*F(1))/.3)                                 C  0111005210
C          END COMPUTATION OF 1/R**2 LOSS                                   C  0111005810
C          COMPUTE ANTENNA PATTERN LOSS                                     C  0111005810
      RTH=SQRT(3./2.)                                                       C  0111005810
      DBANT=-40.*ALOG10(RTH*SIN(XTH))                                       C  0111005A10
C          END COMPUTATION OF ANTENNA LOSS                                  C  0111005D12
      ATT=DBNUND+DBDEV+DBR2+DBANT                                           C  0111005F14
      RETURN                                                                C  0111006011
      END
```

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      SUBROUTINE PATH(R,FPE,FPF,F,P)                                    C  0141000010
      COMMONHE,HFM,HF,HFM,TIME                                          C  0141000020
      DIMENSIONP(4,8)                                                   C  0141000030
                                                                        C  0141000040
C           EVALUATES ANGLES, PATH DISTANCE,DELAY AND DELAY DERIVATIVES  C  0141000050
C           FOR E REGION AND F REGION                                   C  0141000060
C               HE = THICKNESS OF E REGION (KM.)                        C  0141000070
C               HFM = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.) C  0141000080
C               FPE = PENETRATION FREQUENCY OF F REGION (MHZ.)          C  0141000090
C               HF = THICKNESS OF F REGION (KM.)                        C  0141000100
C               HFM = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.) C  0141000110
C               FPF = PENETRATION FREQUENCY OF F REGION (MHZ.)          C  0141000120
C               TIME= TIME OF DAY ('DAY' OR 'NITE')                     C  0141000130
C               R   = LENGTH OF GROUND PATH (KM.)                       C  0141000140
C               F   = FREQUENCY (MHZ.)                                  C  0141000150
C               X   = COS(THETA)I THETA=RAY ANGLE MEASURED FROM VERTICAL C  0141000160
C           SUBROUTINE RETURNS P(I,J)                                   C  0141000170
C               I = 1I LOW  RAY, F REGION                               C  0141000180
C                 = 2I HIGH RAY, F REGION                               C  0141000190
C                 = 3I LOW  RAY, F REGION                               C  0141000200
C                 = 4I HIGH RAY, F REGION                               C  0141000210
C               J = 1I SOLUTION INDICATOR (0=NO SOLUTION, 1=SOLUTION)   C  0141000220
C                 = 2I R=LENGTH OF GROUND PATH (KM.)                    C  0141000230
C                 = 3I X=COS(THETA)                                     C  0141000240
C                 = 4I D=LENGTH OF SIGNAL PATH (KM.)                    C  0141000250
C                 = 5I T=PATH DELAY (SEC.)                              C  0141000260
C                 = 6I D1T=DERIVATIVE OF DELAY (SEC./MHZ.)              C  0141000270
C                 = 7I D2T=SECOND DERIVATIVE OF DELAY (SEC./MHZ.**2)    C  0141000280
C                 = 8I D3T=THIRD DERIVATIVE OF DELAY (SEC./MHZ.**3)     C  0141000290
                                                                        C  0141000300
      FNE=F/FPE                                                         C  0141000310
      FNF=F/FPF                                                         C  0141000312
      IF(FNE-1.)10,10,20                                                C  0141000314
 10   XMIN=1.                                                           C  0141000315
      DO15J=1,8                                                         C  0141000413
      P(2,J)=0.                                                         C  0141000610
      P(3,J)=0.                                                         C  0141000814
      P(4,J)=0.                                                         C  0141000812
 15   CONTINUE                                                          C  0141000915
      GOTO40                                                            C  0141001010
                                                                        C  0141001013
C           DO 30 DETERMINES MINIMUM VALUE OF AF(X)                     C  0141001013
                                                                        C  0141001013
 20   XLAST=1.E-10                                                      C  0141001013
      CALL AE(FPE,F,XLAST,ALAST)                                        C  0141001213
      DO30L=1,9                                                         C  0141001511
      DIFF=1./(10.**L)                                                  C  0141001610
 26   XMIN=XLAST+DIFF                                                   C  0141001613
      IF(FNE+XMIN**1.)27,27,29                                          C  0141001715
 27   CALL AE(FPF,F,XMIN,AMIN)                                          C  0141001613
      IF(AMIN-ALAST)28,29,29                                            C  0141001811
 28   XLAST=XMIN                                                        C  0141001913
      ALAST=AMIN                                                        C  0141002012
      GOTO26                                                            C  0141002111
 29   IF(L-1)36,36,37                                                   C  0141002114
 36   XLAST=XMIN-DIFF                                                   C  0141002215
      GOTO38                                                            C  0141002411
 37   XLAST=XMIN-2.*DIFF                                                C  0141002414
 38   CALL AF(FPF,F,XLAST,ALAST)                                        C  0141002613
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 30   CONTINUE                                                                  C  014:002y11
                                                                                C  014:002b12
C          IF MIN. AE(A) .GT. R, THERE ARE NO RETURNS FROM E REGION            C  014:002b12
                                                                                C  014:002b12
      IF(AMIN-R)40,40,31                                                        C  014:002b12
 31   DO35J=1,8                                                                 C  014:002b14
      P(1,J)=0.                                                                 C  014:002L10
      P(2,J)=0.                                                                 C  014:003U14
 35   CONTINUE                                                                  C  014:003312
      GOTO80                                                                    C  014:003513
                                                                                C  014:003e10
C          DO 50 DETERMINES X = COS(THETA) FOR E REGION LOW RAY                C  014:003e10
                                                                                C  014:003e10
 40   XLAST=1.E-10                                                              C  014:003e10
      DO50L=1,8                                                                 C  014:003B13
      DIFF=1./(10.**L)                                                          C  014:003A10
 46   X=XLAST+DIFF                                                              C  014:003413
      IF(X-XMIN)47,49,49                                                        C  014:003U15
 47   CALL AE(FPE,F,X,A)                                                        C  014:003L15
      IF(A-R)49,49,48                                                           C  014:004113
 48   XLAST=X                                                                   C  014:004215
      GOTO46                                                                    C  014:004514
 49   XLAST=X-DIFF                                                              C  014:004411
 50   CONTINUE                                                                  C  014:004513
      P(1,1)=1.                                                                 C  014:004f14
      P(1,2)=R                                                                  C  014:004815
      X=AMIN1(X,1.)                                                             C  014:004A14
      P(1,3)=X                                                                  C  014:004U12
      P(1,4)=R/SQRT(1.-X**2)                                                    C  014:004f11
      CALL DELAYE(R,FPE,F,X,T,D1T,D2T,D3T)                                      C  014:005415
      P(1,5)=T                                                                  C  014:005713
      P(1,6)=D1T                                                                C  014:005V12
      P(1,7)=D2T                                                                C  014:005B11
      P(1,8)=D3T                                                                C  014:005U10
      IF(FNE-1.)200,200,60                                                      C  014:005L15
                                                                                C  014:006V13
C          DO 70 DETERMINES X = COS(THETA) FOR E REGION HIGH RAY               C  014:006V13
                                                                                C  014:006V13
 60   XLAST=(1./FNE)-1.E-10                                                     C  014:006V13
      DO70L=1,9                                                                 C  014:006J14
      DIFF=1./(10.**L)                                                          C  014:006510
 66   X=XLAST-DIFF                                                              C  014:006713
      IF(X-XMIN)69,69,67                                                        C  014:006815
 67   CALL AE(FPE,F,X,A)                                                        C  014:006V15
      IF(A-R)69,69,68                                                           C  014:006413
 68   XLAST=X                                                                   C  014:006V15
      GOTO66                                                                    C  014:006L14
 69   XLAST=X+DIFF                                                              C  014:006f11
 70   CONTINUE                                                                  C  014:007U13
      P(2,1)=1.                                                                 C  014:007214
      P(2,2)=R                                                                  C  014:007411
      X=AMIN1(X,1.)                                                             C  014:007610
      P(2,3)=X                                                                  C  014:007814
      P(2,4)=R/SQRT(1.-X**2)                                                    C  014:007A13
      CALL DELAYE(R,FPE,F,X,T,D1T,D2T,D3T)                                      C  014:007L11
      P(2,5)=T                                                                  C  014:008215
      P(2,6)=D1T                                                                C  014:008414
      P(2,7)=D2T                                                                C  014:008613
      P(2,8)=D3T                                                                C  014:008812
 80   IF(FNF-1.)90,90,100                                                       C  014:008A11
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 90   XMIN=1.                                                                  C  0141008B12
      DO95J=1,8                                                                C  0141008C10
      P(4,J)=0.                                                                C  0141008D10
 95   CONTINUE                                                                 C  0141008F13
      GOTO120                                                                  C  0141009114
                                                                               C  0141009211
C          DO 110 DETERMINES MINIMUM VALUE OF AF(X)                          C  0141009211
                                                                               C  0141009211
100   XLAST=(1./FNF)+1.E-11                                                    C  0141009211
      CALL AF(FPE,FPL,F,XLAST,ALAST)                                           C  0141009414
      DO110L=1,10                                                              C  0141009715
      DIFF=1./(10.**L)                                                         C  0141009910
106   XMIN=XLAST+DIFF                                                          C  0141009B13
      IF(FNF*XMIN-1.)107,109,109                                               C  0141009C15
107   CALL AF(FPE,FPL,F,XMIN,AMIN)                                             C  0141009E13
      IF(AMIN-ALAST)108,109,109                                                C  014100A114
108   XLAST=XMIN                                                               C  014100A310
      ALAST=AMIN                                                               C  014100A315
      GOTO106                                                                  C  014100A414
109   IF(L-1)116,116,117                                                       C  014100A511
116   XLAST=XMIN-DIFF                                                          C  014100A612
      GOTO118                                                                  C  014100A714
117   XLAST=XMIN-2.*DIFF                                                       C  014100A811
118   CALL AF(FPE,FPL,F,XLAST,ALAST)                                           C  014100AA10
110   CONTINUE                                                                 C  014100AB11
                                                                               C  014100AF12
C          IF MIN. AF(X) .GT. R, THERE ARE NO RETURNS FROM F REGION          C  014100AF12
                                                                               C  014100AF12
      IF(AMIN-R)120,120,111                                                    C  014100AF12
111   DO115J=1,8                                                               C  014100B014
      P(3,J)=0.                                                                C  014100B210
      P(4,J)=0.                                                                C  014100B414
115   CONTINUE                                                                 C  014100B711
      GOTO200                                                                  C  014100B912
                                                                               C  014100B915
C          DO 130 DETERMINES X = COS(THETA) FOR F REGION LOW RAY              C  014100B915
                                                                               C  014100B915
120   XLAST=(1./FNE)+1.E-11                                                    C  014100B915
      DO130L=1,9                                                               C  014100BL14
      DIFF=1./(10.**L)                                                         C  014100BE10
126   X=XLAST+DIFF                                                             C  014100C013
      IF(X-XMIN)127,129,129                                                    C  014100C115
127   CALL AF(FPE,FPL,F,X,A)                                                   C  014100C215
      IF(A-R)129,129,128                                                       C  014100C610
128   XLAST=X                                                                  C  014100C712
      GOTO126                                                                  C  014100C811
129   XLAST=X-DIFF                                                             C  014100C814
130   CONTINUE                                                                 C  014100CA10
      P(3,1)=1.                                                                C  014100CC11
      P(3,2)=K                                                                 C  014100CD15
      X=AMIN1(X,1.)                                                            C  014100CF14
      P(3,3)=X                                                                 C  014100D212
      P(3,4)=K/SQRT(1.-X**2)                                                   C  014100D411
      CALL DELAYF(R,FPL,FPF,F,X,T,D1T,D2T,D3T)                                 C  014100D715
      P(3,5)=1                                                                 C  014100DD10
      P(3,6)=D1T                                                               C  014100DE15
      P(3,7)=D2T                                                               C  014100E014
      P(3,8)=D3T                                                               C  014100E213
      IF(FNF-1.)200,200,140                                                    C  014100E412
                                                                               C  014100E610
```

```
C          DO 150 DETERMINES X = COS(THETA) FOR F REGION HIGH RAY
  140  XLAST=(1./FNF)**2+1.E-11
       DO150L=1,10
       DIFF=1./(10.**L)
  146  X=XLAST-DIFF
       IF(X-XMIN)149,149,147
  147  CALL AF(FPE,FPF,F,X,A)
       IF(A-R)149,149,148
  148  XLAST=X
       GOTO146
  149  XLAST=X+DIFF
  150  CONTINUE
       P(4,1)=1.
       P(4,2)=H
       X=AMIN1(X,1.)
       P(4,3)=X
       P(4,4)=H/SQRT(1.-X**2)
       CALL DELAYF(R,FPE,FPF,F,X,T,D1T,D2T,D3T)
       P(4,5)=T
       P(4,6)=D1T
       P(4,7)=D2T
       P(4,8)=D3T
  200  RETURN
       END
```

```
       SUBROUTINE AE(FPE,F,X,A)
       COMMONHE,HEM,HF,HFM,TIME

C          EVALUATES A(X)=A FOR THE E REGION
C              HE = THICKNESS OF E REGION (KM.)
C              HEM = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)
C              FPE = PENETRATION FREQUENCY OF F REGION (MHZ.)
C              X   = COS(THETA)) THETA=RAY ANGLE MEASURED FROM VERTICAL
C          WARNING: F*X MUST BE LESS THAN FPE

       FFE=F*X/FPE
       A=2.*SQRT((1./X**2)-1.)*(HFM-2.*HE+HF*FFE*ALOG((1.+FFE)/(1.-FFE)))
       RETURN
       END
```

```
C  014100E010
C  014100E010
C  014100E010
C  014100E014
C  014100EA10
C  014100EC13
C  014100ED15
C  014100EE15
C  014100F210
C  014100F312
C  014100F411
C  014100F414
C  014100F810
C  014100F811
C  014100F915
C  014100FB14
C  014100FE12
C  014101U011
C  014101U315
C  014101U910
C  014101UA15
C  014101UC14
C  014101UE13
C  014101U112
C  014101U115
```

```
START OF SEGMENT 015
C  015100U010
C  015100U010
C  015100U010
C  015100U010
C  015100U010
C  015100U010
C  015100U010
C  015100U010
C  015100U010
C  015100U010
C  015100U010
C  015100U010
C  015100U115
C  015100UA11
C  015100UA14
```

```
      SUBROUTINE AF(FPE,FPF,F,X,A)                                          C  017:0000U10
      COMMON HE,HEM,HF,HFM,TIME                                             C  017:0000U10
                                                                            C  017:0000U10
C          EVALUATES A(X)=A FOR THE F REGION                                C  017:0000U10
C              DHE = THICKNESS OF E REGION (KM.)                            C  017:0000U10
C              HEM = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)      C  017:0000U10
C              FPE = PENETRATION FREQUENCY OF E REGION (MHZ.)               C  017:0000U10
C              DHF = THICKNESS OF F REGION (KM.)                            C  017:0000U10
C              HFM = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)      C  017:0000U10
C              FPF = PENETRATION FREQUENCY OF F REGION (MHZ.)               C  017:0000U10
C              TIME= TIME OF DAY ('DAY' OR 'NITE')                          C  017:0000U10
C              F   = FREQUENCY (MHZ.)                                       C  017:0000U10
C              X   = COS(THETA)  THETA=RAY ANGLE MEASURED FROM VERTICAL     C  017:0000U10
C          WARNING: F*X MUST BE GREATER THAN FPE AND LESS THAN FPF           C  017:0000U10
                                                                            C  017:0000U10
      TN='NITE'                                                             C  017:0000U10
      FFF=F*X/FPE                                                           C  017:0000Z13
      FFF=F*X/FPF                                                           C  017:0000Z12
      FFF2=FFF**2                                                           C  017:0000Z11
      FPR=(FPE**2)/(FPF**2)                                                 C  017:0000Z10
      IF(TIME.IS.TN)GOTO10                                                  C  017:0000U10
      A=HEM-2.*HE+HE*FFE*ALOG((FFE+1.)/(FFE-1.))                            C  017:0000A14
      A=A+(HFM-HEM-2.*HF+DQRT(1.-FPR))/SQRT(1.-(1./FFE**2))                 C  017:0001U12
      A=A+2.*HF*FFF*ALOG(SQRT(1.-FPR)+SQRT(FFF2-FPR))/SQRT(1.-FFF2))        C  017:0001Z12
      GOTO20                                                                C  017:0001Z10
   10 A=HEM-2.*HE+2.*HE*FFE*ALOG((FFE+1.)/(FFE-1.))                         C  017:0001Z13
      A=A+HFM-2.*HF-HEM-2.*HE+HF*FFF*ALOG((1.+FFF)/(1.-FFF))                C  017:0002U14
   20 A=A+2.*SQRT((1./A**2)-1.)                                             C  017:0002U15
      RETURN                                                                C  017:0003U12
      END                                                                   C  017:0003U15
```

```
      SUBROUTINE DELAYE(R,FPE,F,X,T,D1T,D2T,D3T)                                C  0181000010
      COMMON/HE/HEM,HF,HFM,TIME                                                 C  0181000020
                                                                                C  0181000030
C          EVALUATES DELAY AND DELAY DERIVATIVES FOR E REGION                   C  0181000040
C              HE = THICKNESS OF E REGION (KM.)                                 C  0181000050
C              HEM = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)          C  0181000060
C              FPE = PENETRATION FREQUENCY OF E REGION (MHZ.)                   C  0181000070
C              R   = LENGTH OF GROUND PATH (KM.)                                C  0181000080
C              F   = FREQUENCY (MHZ.)                                           C  0181000090
C              X   = COS(THETA); THETA=RAY ANGLE MEASURED FROM VERTICAL         C  0181000100
C              T   = SIGNAL PATH DELAY (SEC.)                                   C  0181000110
C              D1T = DERIVATIVE OF DELAY (SEC./MHZ.)                            C  0181000120
C              D2T = SECOND DERIVATIVE OF DELAY (SEC./MHZ.**2)                  C  0181000130
C              D3T = THIRD DERIVATIVE OF DELAY (SEC./MHZ.**3)                   C  0181000140
                                                                                C  0181000150
      C=3.E+05                                                                  C  0181000160
      FNE=F/FPE                                                                 C  0181000283
      FNF2=FNE**2                                                               C  0181000385
      FNF4=FNE**4                                                               C  0181000414
      FFF=FNE*X                                                                 C  0181000611
      FFF2=FFE**2                                                               C  0181000713
      X2=X**2                                                                   C  0181000812
      X4=X**4                                                                   C  0181000913
      V1=X2/(1.-X2)                                                             C  0181000B10
      V2=V1**.5                                                                 C  0181000C14
      V3=V1**1.5                                                                C  0181000F13
      V4=1./((1.-X2)**1.5)                                                      C  0181001213
      V5=1./((1.-X2)**2.5)                                                      C  0181001614
      V6=X2*V5                                                                  C  0181001A14
      W1=1./(1.-FFF2)                                                           C  0181001C10
      W2=W1**2                                                                  C  0181001D13
      W3=W1**3                                                                  C  0181001E12
      Z1=X/F                                                                    C  0181001F15
      T=R/(C*SQRT(1.-X2))                                                       C  0181002111
      T2=T**2                                                                   C  0181002410
      U1=X*T/(1.-X2)                                                            C  0181002415
      U2=(1.+2.*X2)/(X2*T)                                                      C  0181002710
      DEN=R*V3+2.*HEM-4.*HE*W1                                                  C  0181002914
      DXDF=Z1*(R*V2-2.*HE*W+4.*HE*W1)/DEN                                       C  0181002D15
      DXDF2=DXDF**2                                                             C  0181003010
      D1T=U1+DXDF                                                               C  0181003015
      Z2=Z1+DXDF                                                                C  0181003111
      Z3=Z2**2                                                                  C  0181003213
      Z4=1.-3.*X*F*DXDF/(1.-X2)                                                 C  0181003712
      D2XDF=(Z1*(R*V4*Z4*WXDF+8.*HE*F*FNE2*W2*Z3)/DEN)                          C  0181003A15
      D2XDF=D2XDF+(DXDF2/X)-(DXDF/F)                                            C  0181004112
      D2T=U2+(D1T**2)+U1*U2XDF                                                  C  0181004315
      Z5=U2XDF-(DXDF2/X)+(DXDF/F)                                               C  0181004613
      Z6=3.*X*DXDF2+(1.-X2)*D2XDF                                               C  0181004912
      Z7=DXDF2*((1.+X2)/(1.-X2))+Z1*DXDF+X*D2XDF                                C  0181004C13
      Z8=Z1+5.*DXDF+2.*F*W2XDF                                                  C  0181005110
      D3XDF=((DXDF**3)/X2)+(2.*DXDF*U2XDF/X)+(DXDF/(F**2))-(D2XDF/F)-Z5         C  0181005412
     1+((Z1-DXDF)/X)-(Z5+(R*DXDF*V6-8.*HE*X*FNF2*Z2*W2)/DEN)                    C  0181005A12
      D3XDF=D3XDF+(Z1/DEN)*(R*V5*Z4*Z6-3.*F*DXDF*V5*Z7+32.*HE*X*F*FNE4          C  0181006213
     1*W3*(Z2**3)+8.*HE*FNE2*Z2*Z8*W2)                                          C  0181006A11
      D3T=-(3.*(1.+X2+2.*X4)*(D1T**3)/(X4*T2))+3.*U2*D1T+D2T*U1+D3XDF            C  0181007013
      RETURN                                                                    C  0181007813
      END                                                                       C  0181007910
```

```
      SUBROUTINE DELAYF(H,FPE,FPF,F,X,T,D1T,D2T,D3T)                    C 0191000010
      COMMONHE,HEM,HF,HFM,TIME                                          C 0191000010
                                                                        C 0191000010
C          EVALUATES DELAY AND DELAY DERIVATIVES FOR F REGION           C 0191000010
C              HE = THICKNESS OF E REGION (KM.)                         C 0191000010
C              HEM = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)  C 0191000010
C              FPE = PENETRATION FREQUENCY OF E REGION (MHZ.)           C 0191000010
C              HF = THICKNESS OF F REGION (KM.)                         C 0191000010
C              HFM = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)  C 0191000010
C              FPF = PENETRATION FREQUENCY OF F REGION (MHZ.)           C 0191000010
C              H   = LENGTH OF GROUND PATH (KM.)                        C 0191000010
C              F   = FREQUENCY (MHZ.)                                   C 0191000010
C              T   = SIGNAL PATH DELAY (SEC.)                           C 0191000010
C              D1T = DERIVATIVE OF DELAY (SEC./MHZ.)                    C 0191000010
C              D2T = SECOND DERIVATIVE OF DELAY (SEC./MHZ.**2)          C 0191000010
C              D3T = THIRD DERIVATIVE OF DELAY (SEC./MHZ.**3)           C 0191000010
                                                                        C 0191000010
      TH='NITE'                                                         C 0191000010
      C=3.E+05                                                          C 0191000213
      FNE=F/FPE                                                         C 0191000413
      FNE2=FNE**2                                                       C 0191000515
      FFE=FNE*X                                                         C 0191000614
      FFE2=FFE**2                                                       C 0191000810
      FNF=F/FPF                                                         C 0191000815
      FNF2=FNF**2                                                       C 0191000A11
      FFF=FNF*X                                                         C 0191000B10
      FFF2=FFF**2                                                       C 0191000C12
      FFF3=FFF**3                                                       C 0191000D11
      FFF4=FFF**4                                                       C 0191000E14
      FFF5=FFF**4*FNF                                                   C 0191001011
      FFF6=FFF**2*FNF                                                   C 0191001111
      FPR=FPE/FPF                                                       C 0191001213
      FPR2=FPR**2                                                       C 0191001315
      RFPR=SQRT(1.-FPR2)                                                C 0191001414
      X2=X**2                                                           C 0191001513
      X4=X**4                                                           C 0191001714
      V1=1./SQRT(1.-X2)                                                 C 0191001911
      V2=X*V1                                                           C 0191001B12
      V3=X*X2*(V1**3)                                                   C 0191001C14
      V4=V1**3                                                          C 0191001F11
      W1=1./(FFE2-1.)                                                   C 0191002014
      W2=W1**2                                                          C 0191002211
      W3=W1**3                                                          C 0191002310
      W4=(FFE2/(FFE2-1.))**1.5                                          C 0191002413
      W5=W1**2.5                                                        C 0191002613
      W6=W1*W5                                                          C 0191002813
      W7=1./(1.-FFF2)                                                   C 0191002C15
      W8=W7**2                                                          C 0191002E12
      W9=W7**3                                                          C 0191002F11
      W10=FFF2-FPR2                                                     C 0191003014
      W11=SQRT(W10)                                                     C 0191003210
      T=R*V1/C                                                          C 0191003313
      T2=T**2                                                           C 0191003512
      Z1=X/F                                                            C 0191003611
      IF(TIME.IS.TH)GO TO 10                                            C 0191003713
      C1=2.*(HFM-HEM-2.**HF*RFPR)                                       C 0191003911
      C2=RFPR*W11+W10                                                   C 0191003B12
      B=2.*HEM+4.*HE*W1+C1*W4*(4.*HF*FFF3/C2)-4.*HF*FFF3*W7             C 0191003F11
      DXDF=Z1*(R*V2-B)/(R*V3+B)                                         C 0191004810
```

```
      GOTO20                                                                    C  0191004B15
10    B=2.*HFM*8.*HE*W1-4.*HF*W7                                                C  0191004C12
      DXDF=Z1*(R*V2-B)/(R*V3+B)                                                 C  0191005113
20    D1T=X*T*DXDF/(1.-X2)                                                      C  0191005312
      Z2=Z1+DXDF                                                                C  0191005810
      DEN=R*V3+B                                                                C  0191005912
      IF(TIME.LS.TNJGOTO30                                                      C  0191005B11
      ZD1=2.+(RFPM/W11)                                                         C  0191005C15
      C3=C2**2                                                                  C  0191005E14
      FFF6=FFE2*FNE                                                             C  0191005F15
      DBDF=Z2*(8.*HE*X*FNE2*W2-3.*C1*FE6*W5-(12.*HF*FFF6/C2)+(4.*HF*FFF
     15*ZD1/C3)*12.*HF*FFF6*W7-8.*HF*FFF5*W8)                                   C  0191006913
      D2XDF=(UXDF**2/X)-(BXDF/F)+((R*Z1*DXDF*V8+(1.-(3.*X*F*DXDF/(1.-X2
     1)))-Z2*BBDF)/DEN)                                                         C  0191007013
      GOTO40                                                                    C  0191007915
30    D2XDF=(UXDF**2/X)-(BXDF/F)+Z1*((R*DXDF*V8+(1.-(3.*X*F*DXDF/(1.-X2
     1)))+16.*HE*F*FNE2*W8*(Z2**2)+8.*HF*F*FNF2*W8*(Z2**2))/DEN)                C  0191007A12
40    D2T=((D1T**2)*(1.+2.*X2)/(X2*T))+(D2XDF*X*T/(1.-X2))                      C  0191008915
      IF(TIME.LS.TN)GOTO50                                                      C  0191008F14
      C4=C2**3                                                                  C  0191009112
      ZD2=ZD1**2                                                                C  0191009215
      FFF7=FFF3*FFF2*FNF2                                                       C  0191009410
      FFF8=FFF*FNF2                                                             C  0191009515
      FFF9=FFF3*FNF2                                                            C  0191009711
      W12=1./(W11**3)                                                           C  0191009813
      ZD3=2.*Z1+3.*DXDF                                                         C  0191009A12
      ZD4=3.*Z1+2.*DXDF                                                         C  0191009C14
      ZD5=2.*Z1+DXDF                                                            C  0191009F10
      ZD6=5.*Z1+4.*DXDF                                                         C  0191009A15
      ZD7=5.*FFF2                                                               C  0191009A81
      ZD8=3.*FFF2                                                               C  0191009A83
      ZD9=D2XDF                                                                 C  0191009A85
      ZD10=3.*ZD4*FFF2*ZD8                                                      C  0191009A84
      D2BDF=((DXDF-Z1+F*D2XDF)/(F*Z2))*DBDF+Z2*(-8.*HE*FNE2*(FFE2*ZD3+Z         C  0191009A90
     1D5)*W3+FFA*3.*C1*(4D4+FFF2*ZD3)*W6+(12.*HF*FFFA*(-ZD4+FFF2*Z2*ZD
     21)/C2)+(4.*HF*FFF9*4D6*ZD1/C3)*(4.*HF*FFF7*RFPR*Z2*W12/C3)*(8.*HF         C  0191009B15
     3*FFF7*Z2*ZD2/C4)*16.*HF*FFF9*Z2*ZD8*W9-4.*HF*FFF8*ZD10*W8)                C  0191009B85
      DXDF2=DXDF**2                                                             C  0191009C15
      D3XDF=-((DXDF**3)/X4)+(2.*DXDF*D2XDF/X)+(DXDF/(F**2))-(D2XDF/F)*(         C  0191009C90
     11./DEN)*(-3.*HE*X*DXHF*(V1**5)*(((1.+4.*X2)/(1.-X2))*DXDF2+Z1*DXDF       C  0191009D10
     2+3.*X*D2XDF)+(R*V4/F)*(((1.+2.*X2)/(1.-X2))*DXDF2-Z1*DXDF+X*ZD9)-         C  0191009D90
     3(1./F)*(2.*UXDF-Z1+Z.*F*D2XDF-(UXDF2/Z1))*DBDF-Z2*D2BDF)                  C  0191009E13
      GOTO60                                                                    C  0191009E74
50    DXDF2=DXDF**2                                                             C  0191009E81
      ZN1=D2XUF-(UXUF2/X)+(DXUF/F)                                              C  0191009E92
      ZN2=Z1+5.*DXDF+2.*F*D2XDF                                                 C  0191009F81
      ZN3=V1**5                                                                 C  0191009F93
      ZN4=Z2**3                                                                 C  0191009FA2
      ZZ=Z1-DXDF                                                                C  0191009FB5
      D3XUF=-((DXDF**3)/XX)+(2.*DXDF*D2XDF/X)+(DXDF/(F**2))-(D2XDF/F)-(         C  0191009FA1
     1ZZ+ZN1/X)*(ZN1/DEN)*(R*3.*X2*DXUF*ZN3-16.*HE*X*FNE2*Z2*W2-8.*HF*X         C  0191009FA1
     2*FNF2*Z2*W8)+(Z1/DEN)*(R*ZN3*(1.-(3.*X*F*DXDF/(1.-X2)))*(3.*X*DXD         C  0191010A11
     3F2+(1.-A2)*D2XUF)-3.*R*F*DXDF*ZN3*(((1.+X2)/(1.-X2))*DXDF2+Z1*DXD         C  0191010B12
     4F*X*D2XDF)*64.*HE*X*F*(FNF2**2)*ZN4*W3+32.*HF*X*F*(FNF2**2)*ZN4*W         C  0191011210
     59+16.*HE*FNE2*Z2*ZN2*W2+A.*HF*FNF2*Z2*ZN2*W8)                             C  0191011B13
60    D3T=-(3./(X4*12))*Z1.*X2+2.*X4)*(D1T**3)+(3./(X2*T))*(1.+2.*X2)*D         C  0191012313
     11T+D2T+(X*T/(1.-X2))*D3XDF                                                C  0191012A14
      RETURN                                                                    C  0191012B14
      END                                                                       C  0191012F11
```

```
      SUBROUTINE DEVIAT(F,X,XNU,DBDEV)                                  C  01A:000010
      DIMENSION F(3),XNU(4)                                             C  01A:000010
      COMMON HE,HEM,HF,HFM,TIME                                         C  01A:000010
C                                                                       C  01A:000010
C          ***** PROGRAM WRITTEN DECEMBER 1977 *****                    C  01A:000010
C                                                                       C  01A:000010
C          SUBROUTINE COMPUTES DEVIATIVE ABSORPTION                     C  01A:000010
C                                                                       C  01A:000010
C          GLOSSARY OF MOST IMPORTANT TERMS                             C  01A:000010
C               AHE    = THICKNESS OF E REGION (KM.)                   C  01A:000010
C               HEM    = HEIGHT OF MAX. ELECTRON DENSITY IN E REGION (KM.)  01A:000010
C               F(2)   = PENETRATION FREQUENCY OF E REGION (MHZ.)      C  01A:000010
C               AHF    = THICKNESS OF F REGION (KM.)                   C  01A:000010
C               HFM    = HEIGHT OF MAX. ELECTRON DENSITY IN F REGION (KM.)  01A:000010
C               F(3)   = PENETRATION FREQUENCY OF F REGION (MHZ.)      C  01A:000010
C               X      = COS(THETA))THETA=RAY ANGLE MEASURED FROM VERTICAL  01A:000010
C               F(1)   = CARRIER FREQUENCY (MHZ.)                      C  01A:000010
C               TIME   = TIME OF DAY ('DAY' OR 'NITE')                 C  01A:000010
C               C      = VELOCITY OF LIGHT (KM/SEC)                    C  01A:000010
C               XNU(1)= COLLISION FREQ. AT HEIGHT HEM (MHZ.)           C  01A:000010
C               XNU(2)= COLLISION FREQ. AT HEIGHT HFM (MHZ.)           C  01A:000010
C               DBDEV = DEVIATIVE ABSORPTION (DB.)                     C  01A:000010
C                                                                       C  01A:000010
      C=3.E+05                                                          C  01A:000010
      TN='NITE'                                                         C  01A:000213
      FNEX=(F(1)*X)/F(2)                                                C  01A:000413
      FNFX=(F(1)*X)/F(3)                                                C  01A:000712
      SE=FNEX*(1./FNEX)                                                 C  01A:000A12
      IF(FNEX-1.)10,11,12                                               C  01A:000C10
   10 EE=(1.+FNEX)/(1.-FNEX)                                            C  01A:000F11
      DBNEV=XNU(1)*HE*(.5*SE*ALOG(EE)-1.)                               C  01A:001111
      GOTO190                                                           C  01A:001314
   11 DBDEV=2000.                                                       C  01A:001711
      GOTO200                                                           C  01A:001811
   12 IF(FNFX-1.)14,13,13                                               C  01A:001814
   13 DBDEV=2000.                                                       C  01A:001915
      GOTO200                                                           C  01A:001A15
   14 SF=FNFX*(1./FNFX)                                                 C  01A:001B12
      R2=(F(2)/F(3))**2                                                 C  01A:001D10
      RR=SQRT(1.-R2)                                                    C  01A:002011
      EE=(FNEX+1.)/(FNEX-1.)                                            C  01A:002210
      IF(TIME.IS.TN)GOTO15                                              C  01A:002410
      EF=(RR+SQRT(FNFX**2-R2))/SQRT(1.-FNFX**2)                         C  01A:002514
      EG=(RR+SQRT(FNFX**2-R2))/FNFX                                     C  01A:002A12
      EM=1./(FNEX+SQRT(FNEX**2-1.))                                     C  01A:002D14
      DBNEV=XNU(1)*HE*(.5*SE*ALOG(EE)-1.)+XNU(2)*HF*SF*ALOG(EF)+XNU(1)*H  01A:003014
     1E*FM*XNU(2)*HF*EG                                                 C  01A:003A13
      GOTO190                                                           C  01A:003E15
   15 EF=(1.+FNFX)/(1.-FNFX)                                            C  01A:003F12
      DBNEV=2.*XNU(1)*HE*(.5*SE*ALOG(EE)-1.)+XNU(2)*HF*(.5*SF*ALOG(EF)-1  01A:004112
     1.)                                                                C  01A:004614
  190 DBNEV=(3.686*DBDEV)/(X*C)                                         C  01A:004915
  200 RETURN                                                            C  01A:005110
      END                                                               C  01A:005113
```

```
      SUBROUTINE TEMP(H,T)                                                  C  01B:000010
                                                                            C  01B:000010
C           SUBROUTINE COMPUTES TEMPERATURE AT HEIGHT H USING POWER         C  01B:000010
C           SERIES FIT TO TABLE IN 1959 ARDC MODEL ATMOSPHERE. TWO          C  01B:000010
C           DIFFERENT SERIES ARE USED, ONE FOR HEIGHTS BETWEEN 100 KM.      C  01B:000010
C           AND 210 KM., AND ANOTHER FOR HEIGHTS BETWEEN 210 KM. AND        C  01B:000010
C           600 KM.                                                         C  01B:000010
                                                                            C  01B:000010
C           ***** PROGRAM WRITTEN JANUARY 1978 *****                        C  01B:000010
                                                                            C  01B:000010
C               H = HEIGHT (KM.)                                            C  01B:000010
C               T = TEMPERATURE (DEG. K)                                    C  01B:000010
                                                                            C  01B:000010
      IF(H-100.)50,5,5                                                      C  01B:000010
    5 IF(H-210.)10,15,15                                                    C  01B:000112
   10 A=1414.                                                               C  01B:000214
      B=-44.28                                                              C  01B:000314
      C=.4217                                                               C  01B:000514
      D=-1.004E-03                                                          C  01B:000713
      GOTO25                                                                C  01B:000914
   15 IF(H-600.)20,20,50                                                    C  01B:000A11
   20 A=1423./                                                              C  01B:000B14
      B=.0399                                                               C  01B:000D13
      C=-.00104                                                             C  01B:000F13
      D=3.E-06                                                              C  01B:001114
   25 T=A+H*(B+H*(C+D*H))                                                   C  01B:001313
      GOTO100                                                               C  01B:001712
   50 WRITE(6,95)                                                           C  01B:001715
   95 FORMAT(1X,'***** WARNING: THE HEIGHT OF THE PEAK ELECTRON DENSITY     C  01B:001812
     1LIES OUTSIDE THE ACCEPTABLE RANGE FOR THE SERIES APPROXIMATIONS US    C  01B:001812
     2ED *****')                                                            C  01B:001812
  100 RETURN                                                                C  01B:001812
      END                                                                   C  01B:001815
```

```
      SUBROUTINE GNDATN(F,IS,R,GATTEN)                                  C  01C:0000010
      DIMENSION XA(6,8,13),FF(8),RR(13)                                 C  01C:0000020
C                                                                       C  01C:0000030
C     ***** PROGRAM WRITTEN MARCH 1978 *****                            C  01C:0000040
C                                                                       C  01C:0000050
C     SUBROUTINE COMPUTES ATTENUATION OF GROUNDWAVE. THIS ATTEN-        C  01C:0000060
C     UATION CONSISTS OF TWO COMPONENTS--A BASIC LOSS TERM, XLBASC,     C  01C:0000070
C     DUE TO THE SPREAD OF SIGNAL ENERGY OVER A CURVED, LOSSY OCEAN     C  01C:0000080
C     SURFACE; AND AN ADDED LOSS TERM, XLADD, DUE TO RANDOM             C  01C:0000090
C     SURFACE IRREGULARITIES USING THE PHILLIPS ISOTROPIC WAVE          C  01C:0000100
C     SPECTRUM. BOTH LOSS TERMS ARE OBTAINED FROM BARRICK (1970).       C  01C:0000110
C                                                                       C  01C:0000120
C     GLOSSARY OF MOST IMPORTANT TERMS                                  C  01C:0000130
C         F      = CARRIER FREQUENCY (MHZ.)                             C  01C:0000140
C         R      = GROUND DISTANCE BETWEEN XMTR. AND RCVR. (KM.)        C  01C:0000150
C         IS     = SEA STATE                                            C  01C:0000160
C         XLBASC = BASIC LOSS (DB.)                                     C  01C:0000170
C                  XLBASC=20.*ALOG10(2.*PI*R*F/.3)+D.*(R**E)            C  01C:0000180
C                         +D1*(F**D2)*EXP(D3*(F**5))                    C  01C:0000190
C                         +F1*(F**E2)                                   C  01C:0000200
C         XLADD  = ADDED LOSS (DB.)                                     C  01C:0000210
C                  ADDED LOSS IS CALCULATED BY INTERPOLATING BETWEEN    C  01C:0000220
C                  VALUES FROM BARRICK'S CURVES. THE ARRAY XA           C  01C:0000230
C                  CONTAINS THE VALUES FOR THIS INTERPOLATION.          C  01C:0000240
C                                                                       C  01C:0000250
C     THE ARRAY XA(IS,IF,IR) CONTAINS THE FOLLOWING REFERENCE           C  01C:0000260
C     VALUES                                                            C  01C:0000270
C         IS =  SEA STATE                                               C  01C:0000280
C         IF =  1: FREQ. =  3.0 MHZ.                                    C  01C:0000290
C            =  2: FREQ. =  5.0 MHZ.                                    C  01C:0000300
C            =  3: FREQ. =  7.0 MHZ.                                    C  01C:0000310
C            =  4: FREQ. = 10.0 MHZ.                                    C  01C:0000320
C            =  5: FREQ. = 15.0 MHZ.                                    C  01C:0000330
C            =  6: FREQ. = 20.0 MHZ.                                    C  01C:0000340
C            =  7: FREQ. = 30.0 MHZ.                                    C  01C:0000350
C         IR =  1: RANGE =   25 KM.                                     C  01C:0000360
C            =  2: RANGE =   50 KM.                                     C  01C:0000370
C            =  3: RANGE =  100 KM.                                     C  01C:0000380
C            =  4: RANGE =  200 KM.                                     C  01C:0000390
C            =  5: RANGE =  300 KM.                                     C  01C:0000400
C            =  6: RANGE =  400 KM.                                     C  01C:0000410
C            =  7: RANGE =  500 KM.                                     C  01C:0000420
C            =  8: RANGE =  600 KM.                                     C  01C:0000430
C            =  9: RANGE =  700 KM.                                     C  01C:0000440
C            = 10: RANGE =  800 KM.                                     C  01C:0000450
C            = 11: RANGE =  900 KM.                                     C  01C:0000460
C            = 12: RANGE = 1000 KM.                                     C  01C:0000470
C                                                                       C  01C:0000480
C                                                                       C  01C:0000490
C     WARNING: THE RECOMMENDED RANGES AND FREQUENCIES FOR               C  01C:0000500
C              INTERPOLATION LIE BETWEEN 25 KM. - 1000 KM. AND          C  01C:0000510
C              3 MHZ. - 30 MHZ. RESPECTIVELY. IF EITHER THE RANGE       C  01C:0000520
C              OR FREQUENCY LIES OUTSIDE THESE LIMITS, A WARNING        C  01C:0000530
C              STATEMENT IS PRINTED AND THE GROUNDWAVE ATTENUATION      C  01C:0000540
C              IS SET EQUAL TO 1.0E+04.                                 C  01C:0000550
C                                                                       C  01C:0000560
C                                                                       C  01C:0000570
C                                                                       C  01C:0000580
      PI=3.14159265359                                                  C  01C:0000590
```

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C          ASSIGN VALUES TO CONSTANTS USED IN XLRASC                    C  01C:000510
      D1=1.78E-04                                                       C  01C:000510
      D2=2.58                                                           C  01C:000713
      D3=-1.48E-08                                                      C  01C:000913
      E1=1.83                                                           C  01C:000B14
      E2=-.243                                                          C  01C:000D13
C          END ASSIGNMENT OF VALUES TO CONSTANTS IN XLRASC              C  01C:000F14
C          ASSIGN REFERENCE FREQUENCY VALUES TO ARRAY FF                C  01C:000F14
      FF(1)=3.                                                          C  01C:000F14
      FF(2)=5.                                                          C  01C:001015
      FF(3)=7.                                                          C  01C:001210
      FF(4)=10.                                                         C  01C:001412
      FF(5)=15.                                                         C  01C:001614
      FF(6)=20.                                                         C  01C:001810
      FF(7)=30.                                                         C  01C:001A12
C          END ASSIGNMENT OF REFERENCE FREQUENCIES                      C  01C:001B14
C          ASSIGN REFERENCE RANGE VALUES TO ARRAY RR                    C  01C:001B14
      RR(1)=25.                                                         C  01C:001B14
      RR(2)=50.                                                         C  01C:001D15
      RR(3)=100.                                                        C  01C:001F10
      RR(4)=200.                                                        C  01C:002112
      RR(5)=300.                                                        C  01C:002314
      RR(6)=400.                                                        C  01C:002511
      RR(7)=500.                                                        C  01C:002714
      RR(8)=600.                                                        C  01C:002911
      RR(9)=700.                                                        C  01C:002B14
      RR(10)=800.                                                       C  01C:002D11
      RR(11)=900.                                                       C  01C:002F14
      RR(12)=1000.                                                      C  01C:002F11
C          END ASSIGNMENT OF REFERENCE RANGES                           C  01C:003114
C          ASSIGN VALUES TO ARRAY XA                                    C  01C:003114
      XA(1,1, 1)=-.60000E-01                                            C  01C:003314
      XA(1,1, 2)=-.75000E-01                                            C  01C:003512
      XA(1,1, 3)=-.10000E+00                                            C  01C:003712
      XA(1,1, 4)=-.15000E+00                                            C  01C:003912
      XA(1,1, 5)=-.20000E+00                                            C  01C:003B12
      XA(1,1, 6)=-.25000E+00                                            C  01C:003D12
      XA(1,1, 7)=-.30000E+00                                            C  01C:003F12
      XA(1,1, 8)=-.34000E+00                                            C  01C:003F12
      XA(1,1, 9)=-.40000E+00                                            C  01C:004112
      XA(1,1,10)=-.45000E+00                                            C  01C:004312
      XA(1,1,11)=-.49000E+00                                            C  01C:004512
      XA(1,1,12)=-.55000E+00                                            C  01C:004A12
      XA(1,2, 1)=0.                                                     C  01C:004B12
      XA(1,2, 2)=-.60000E-01                                            C  01C:004E13
      XA(1,2, 3)=-.90000E-01                                            C  01C:005112
      XA(1,2, 4)=-.12000E+00                                            C  01C:005412
      XA(1,2, 5)=-.15000E+00                                            C  01C:005712
      XA(1,2, 6)=-.18000E+00                                            C  01C:005A12
      XA(1,2, 7)=-.20000E+00                                            C  01C:005D12
      XA(1,2, 8)=-.24000E+00                                            C  01C:006012
      XA(1,2, 9)=-.27000E+00                                            C  01C:006312
      XA(1,2,10)=-.35000E+00                                            C  01C:006612
      XA(1,2,11)=-.40000E+00                                            C  01C:006912
      XA(1,2,12)=-.48000E+00                                            C  01C:006C12
      XA(1,3, 1)=0.                                                     C  01C:006F12
      XA(1,3, 2)=0.                                                     C  01C:007013
      XA(1,3, 3)=-.13000E+00                                            C  01C:007314
      XA(1,3, 4)=-.15000E+00                                            C  01C:007412
      XA(1,3, 5)=-.17000E+00                                            C  01C:007712
```

```
      XA(1,3, 6)=-.18000E+00
      XA(1,3, 7)=-.19000E+00
      XA(1,3, 8)=-.20000E+00
      XA(1,3, 9)=-.20000E+00
      XA(1,3,10)=-.22000E+00
      XA(1,3,11)=-.23000E+00
      XA(1,3,12)=-.25000E+00
      XA(1,4, 1)=0.
      XA(1,4, 2)=0.
      XA(1,4, 3)=0.
      XA(1,4, 4)=0.
      XA(1,4, 5)=0.
      XA(1,4, 6)= .12000E+00
      XA(1,4, 7)= .20000E+00
      XA(1,4, 8)= .26500E+00
      XA(1,4, 9)= .35000E+00
      XA(1,4,10)= .45000E+00
      XA(1,4,11)= .60000E+00
      XA(1,4,12)= .80000E+00
      XA(1,5, 1)=0.
      XA(1,5, 2)= .10000E+00
      XA(1,5, 3)= .21000E+00
      XA(1,5, 4)= .56000E+00
      XA(1,5, 5)= .85000E+00
      XA(1,5, 6)= .12000E+01
      XA(1,5, 7)= .14000E+01
      XA(1,5, 8)= .16500E+01
      XA(1,5, 9)= .20000E+01
      XA(1,5,10)= .23000E+01
      XA(1,5,11)= .25500E+01
      XA(1,5,12)= .28000E+01
      XA(1,6, 1)=0.
      XA(1,6, 2)= .30000E+00
      XA(1,6, 3)= .80000E+00
      XA(1,6, 4)= .12000E+01
      XA(1,6, 5)= .17000E+01
      XA(1,6, 6)= .19000E+01
      XA(1,6, 7)= .23000E+01
      XA(1,6, 8)= .27000E+01
      XA(1,6, 9)= .32000E+01
      XA(1,6,10)= .38000E+01
      XA(1,6,11)= .40500E+01
      XA(1,6,12)= .46000E+01
      XA(1,7, 1)= .45000E+00
      XA(1,7, 2)= .10000E+01
      XA(1,7, 3)= .13000E+01
      XA(1,7, 4)= .18000E+01
      XA(1,7, 5)= .20000E+01
      XA(1,7, 6)= .24000E+01
      XA(1,7, 7)= .27000E+01
      XA(1,7, 8)= .30500E+01
      XA(1,7, 9)= .37000E+01
      XA(1,7,10)= .40000E+01
      XA(1,7,11)= .44000E+01
      XA(1,7,12)= .49000E+01
      XA(2,1, 1)=-.12000E+00
      XA(2,1, 2)=-.15000E+00
      XA(2,1, 3)=-.20000E+00
      XA(2,1, 4)=-.30000E+00
      XA(2,1, 5)=-.40000E+00
```

```
C  01C:007A:2
C  01C:007D:2
C  01C:0080:2
C  01C:0083:2
C  01C:0086:2
C  01C:0089:2
C  01C:008C:2
C  01C:008F:2
C  01C:0092:3
C  01C:0095:4
C  01C:0097:5
C  01C:0094:0
C  01C:0095:1
C  01C:0098:1
C  01C:009B:1
C  01C:009E:1
C  01C:00A1:1
C  01C:00A4:1
C  01C:00A7:1
C  01C:00AA:1
C  01C:00AD:2
C  01C:00AE:1
C  01C:00B1:1
C  01C:00B4:1
C  01C:00B7:1
C  01C:00BA:1
C  01C:00BD:1
C  01C:00C0:1
C  01C:00C1:4
C  01C:00C4:1
C  01C:00C7:1
C  01C:00CA:1
C  01C:00CD:2
C  01C:00CE:1
C  01C:00D1:1
C  01C:00D4:1
C  01C:00D7:1
C  01C:00DA:1
C  01C:00DD:1
C  01C:00E0:1
C  01C:00E3:1
C  01C:00E6:1
C  01C:00E9:1
C  01C:00EC:1
C  01C:00EF:1
C  01C:00F0:2
C  01C:00F3:1
C  01C:00F6:1
C  01C:00F7:3
C  01C:00FA:1
C  01C:00FD:1
C  01C:0100:1
C  01C:0103:1
C  01C:0104:4
C  01C:0107:1
C  01C:010A:1
C  01C:010D:2
C  01C:0110:2
C  01C:0112:2
C  01C:0115:2
```

```
XA(2,1, 6)=-.50000E+00
XA(2,1, 7)=-.60000E+00
XA(2,1, 8)=-.68000E+00
XA(2,1, 9)=-.80000E+00
XA(2,1,10)=-.90000E+00
XA(2,1,11)=-.98000E+00
XA(2,1,12)=-.11000E+01
XA(2,2, 1)=-.25000E+00
XA(2,2, 2)=-.30000E+00
XA(2,2, 3)=-.40000E+00
XA(2,2, 4)=-.55000E+00
XA(2,2, 5)=-.69000E+00
XA(2,2, 6)=-.80000E+00
XA(2,2, 7)=-.95000E+00
XA(2,2, 8)=-.11100E+01
XA(2,2, 9)=-.12700E+01
XA(2,2,10)=-.14200E+01
XA(2,2,11)=-.16000E+01
XA(2,2,12)=-.18200E+01
XA(2,3, 1)=-.30000E+00
XA(2,3, 2)=-.40000E+00
XA(2,3, 3)=-.50000E+00
XA(2,3, 4)=-.62000E+00
XA(2,3, 5)=-.65000E+00
XA(2,3, 6)=-.76000E+00
XA(2,3, 7)=-.85000E+00
XA(2,3, 8)=-.90000E+00
XA(2,3, 9)=-.10000E+01
XA(2,3,10)=-.11500E+01
XA(2,3,11)=-.12000E+01
XA(2,3,12)=-.12500E+01
XA(2,4, 1)=-.40000E+00
XA(2,4, 2)=-.40000E+00
XA(2,4, 3)=-.10000E+00
XA(2,4, 4)= .40000E+00
XA(2,4, 5)= .90000E+00
XA(2,4, 6)= .14000E+01
XA(2,4, 7)= .19000E+01
XA(2,4, 8)= .24000E+01
XA(2,4, 9)= .29000E+01
XA(2,4,10)= .33000E+01
XA(2,4,11)= .37500E+01
XA(2,4,12)= .42000E+01
XA(2,5, 1)= .20000E+00
XA(2,5, 2)= .85000E+00
XA(2,5, 3)= .23000E+01
XA(2,5, 4)= .42000E+01
XA(2,5, 5)= .57000E+01
XA(2,5, 6)= .71000E+01
XA(2,5, 7)= .86000E+01
XA(2,5, 8)= .99000E+01
XA(2,5, 9)= .11400E+02
XA(2,5,10)= .13000E+02
XA(2,5,11)= .14900E+02
XA(2,5,12)= .17000E+02
XA(2,6, 1)= .11500E+01
XA(2,6, 2)= .26000E+01
XA(2,6, 3)= .42000E+01
XA(2,6, 4)= .55000E+01
XA(2,6, 5)= .68000E+01
```

```
C  01C:011812
C  01C:011B12
C  01C:011E12
C  01C:012112
C  01C:012412
C  01C:012712
C  01C:012A12
C  01C:012D12
C  01C:013012
C  01C:013312
C  01C:013612
C  01C:013912
C  01C:013C12
C  01C:013F12
C  01C:014212
C  01C:014512
C  01C:014812
C  01C:014B12
C  01C:014E12
C  01C:015112
C  01C:015412
C  01C:015712
C  01C:015A12
C  01C:015D12
C  01C:016012
C  01C:016312
C  01C:016612
C  01C:016912
C  01C:016A15
C  01C:016D12
C  01C:017012
C  01C:017312
C  01C:017612
C  01C:017912
C  01C:017C12
C  01C:017F11
C  01C:018211
C  01C:018511
C  01C:018811
C  01C:018B11
C  01C:018E11
C  01C:019111
C  01C:019411
C  01C:019711
C  01C:019A11
C  01C:019D11
C  01C:01A011
C  01C:01A311
C  01C:01A611
C  01C:01A911
C  01C:01AC11
C  01C:01AF11
C  01C:01B211
C  01C:01B514
C  01C:01B811
C  01C:01B714
C  01C:01BA11
C  01C:01BD11
C  01C:01C011
C  01C:01C311
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```
XA(2,6, 6)= .80000E+01
XA(2,6, 7)= .93000E+01
XA(2,6, 8)= .10650E+02
XA(2,6, 9)= .12000E+02
XA(2,6,10)= .13300E+02
XA(2,6,11)= .14600E+02
XA(2,6,12)= .16000E+02
XA(2,7, 1)= .33500E+01
XA(2,7, 2)= .42500E+01
XA(2,7, 3)= .42500E+01
XA(2,7, 4)= .49000E+01
XA(2,7, 5)= .58000E+01
XA(2,7, 6)= .66000E+01
XA(2,7, 7)= .77000E+01
XA(2,7, 8)= .83500E+01
XA(2,7, 9)= .92000E+01
XA(2,7,10)= .10100E+02
XA(2,7,11)= .10950E+02
XA(2,7,12)= .11900E+02
XA(3,1, 1)=-.24000E+00
XA(3,1, 2)=-.32500E+00
XA(3,1, 3)=-.42500E+00
XA(3,1, 4)=-.60000E+00
XA(3,1, 5)=-.76000E+00
XA(3,1, 6)=-.93500E+00
XA(3,1, 7)=-.11150E+01
XA(3,1, 8)=-.12780E+01
XA(3,1, 9)=-.14750E+01
XA(3,1,10)=-.16750E+01
XA(3,1,11)=-.18550E+01
XA(3,1,12)=-.20680E+01
XA(3,2, 1)=-.50000E+00
XA(3,2, 2)=-.53000E+00
XA(3,2, 3)=-.67000E+00
XA(3,2, 4)=-.78000E+00
XA(3,2, 5)=-.90000E+00
XA(3,2, 6)=-.10000E+01
XA(3,2, 7)=-.11700E+01
XA(3,2, 8)=-.13000E+01
XA(3,2, 9)=-.14700E+01
XA(3,2,10)=-.16000E+01
XA(3,2,11)=-.18000E+01
XA(3,2,12)=-.20000E+01
XA(3,3, 1)=-.30000E+00
XA(3,3, 2)=-.15000E+00
XA(3,3, 3)= .20000E+00
XA(3,3, 4)= .60000E+00
XA(3,3, 5)= .12000E+01
XA(3,3, 6)= .16500E+01
XA(3,3, 7)= .21000E+01
XA(3,3, 8)= .25000E+01
XA(3,3, 9)= .30500E+01
XA(3,3,10)= .38000E+01
XA(3,3,11)= .41500E+01
XA(3,3,12)= .48000E+01
XA(3,4, 1)= .20000E+00
XA(3,4, 2)= .70000E+00
XA(3,4, 3)= .17000E+01
XA(3,4, 4)= .36000E+01
XA(3,4, 5)= .52000E+01
```

```
C  01C:01C0:1
C  01C:01C7:4
C  01C:01CA:1
C  01C:01CD:1
C  01C:01CE:4
C  01C:01D1:1
C  01C:01D4:1
C  01C:01D7:4
C  01C:01DA:1
C  01C:01DD:1
C  01C:01E1:1
C  01C:01E4:1
C  01C:01E7:1
C  01C:01EA:1
C  01C:01ED:1
C  01C:01F0:1
C  01C:01F3:1
C  01C:01F6:1
C  01C:01F9:1
C  01C:01FC:2
C  01C:0202:2
C  01C:0205:2
C  01C:0208:2
C  01C:020B:2
C  01C:020E:2
C  01C:0211:2
C  01C:0214:2
C  01C:0217:2
C  01C:021A:2
C  01C:021D:2
C  01C:0220:2
C  01C:0223:2
C  01C:0226:2
C  01C:0229:2
C  01C:022C:2
C  01C:022D:4
C  01C:0231:2
C  01C:0234:2
C  01C:0237:2
C  01C:023A:2
C  01C:023E:0
C  01C:0240:2
C  01C:0243:2
C  01C:0246:1
C  01C:0249:1
C  01C:024C:1
C  01C:024F:1
C  01C:0252:1
C  01C:0255:1
C  01C:0258:1
C  01C:025B:1
C  01C:025E:1
C  01C:0261:1
C  01C:0264:1
C  01C:0267:1
C  01C:026A:1
C  01C:026D:1
```

```
XA(3,4, 6)= .67000E+01
XA(3,4, 7)= .82000E+01
XA(3,4, 8)= .96000E+01
XA(3,4, 9)= .11300E+02
XA(3,4,10)= .12800E+02
XA(3,4,11)= .14250E+02
XA(3,4,12)= .15700E+02
XA(3,5, 1)= .12000E+01
XA(3,5, 2)= .28000E+01
XA(3,5, 3)= .50000E+01
XA(3,5, 4)= .78000E+01
XA(3,5, 5)= .99000E+01
XA(3,5, 6)= .11900E+02
XA(3,5, 7)= .14100E+02
XA(3,5, 8)= .16250E+02
XA(3,5, 9)= .18400E+02
XA(3,5,10)= .20600E+02
XA(3,5,11)= .22700E+02
XA(3,5,12)= .24900E+02
XA(3,6, 1)= .25000E+01
XA(3,6, 2)= .48000E+01
XA(3,6, 3)= .68000E+01
XA(3,6, 4)= .82000E+01
XA(3,6, 5)= .99000E+01
XA(3,6, 6)= .11600E+02
XA(3,6, 7)= .13300E+02
XA(3,6, 8)= .14100E+02
XA(3,6, 9)= .16800E+02
XA(3,6,10)= .18600E+02
XA(3,6,11)= .20450E+02
XA(3,6,12)= .22300E+02
XA(3,7, 1)= .55500E+01
XA(3,7, 2)= .62000E+01
XA(3,7, 3)= .62000E+01
XA(3,7, 4)= .72000E+01
XA(3,7, 5)= .82000E+01
XA(3,7, 6)= .93000E+01
XA(3,7, 7)= .10400E+02
XA(3,7, 8)= .11450E+02
XA(3,7, 9)= .12600E+02
XA(3,7,10)= .13700E+02
XA(3,7,11)= .14800E+02
XA(3,7,12)= .15900E+02
XA(4,1, 1)=-.36000E+00
XA(4,1, 2)=-.50000E+00
XA(4,1, 3)=-.65000E+00
XA(4,1, 4)=-.90000E+00
XA(4,1, 5)=-.11200E+01
XA(4,1, 6)=-.13700E+01
XA(4,1, 7)=-.16300E+01
XA(4,1, 8)=-.18750E+01
XA(4,1, 9)=-.21500E+01
XA(4,1,10)=-.24500E+01
XA(4,1,11)=-.27300E+01
XA(4,1,12)=-.30410E+01
XA(4,2, 1)=-.25000E+00
XA(4,2, 2)=-.20000E+00
XA(4,2, 3)= .10000E+00
XA(4,2, 4)= .35000E+00
XA(4,2, 5)= .65000E+00
```

```
C  01C:027Dt1
C  01C:027Et1
C  01C:027Ft1
C  01C:0280t1
C  01C:0281t1
C  01C:0282t1
C  01C:0283t1
C  01C:0284t1
C  01C:0285t1
C  01C:0286t3
C  01C:0287t1
C  01C:0292t1
C  01C:0295t1
C  01C:0296t1
C  01C:0297t1
C  01C:0298t1
C  01C:02A1t1
C  01C:02A4t1
C  01C:02A7t1
C  01C:02AAt1
C  01C:02ADt1
C  01C:02B0t1
C  01C:02B3t1
C  01C:02B6t1
C  01C:02B9t1
C  01C:02BCt1
C  01C:02BFt1
C  01C:02C2t1
C  01C:02C5t1
C  01C:02C8t1
C  01C:02CBt1
C  01C:02CEt1
C  01C:02D1t1
C  01C:02D4t1
C  01C:02D7t1
C  01C:02DAt1
C  01C:02DDt1
C  01C:02E0t1
C  01C:02E3t1
C  01C:02E6t1
C  01C:02E9t1
C  01C:02ECt1
C  01C:02EFt1
C  01C:02F2t2
C  01C:02F5t2
C  01C:02F8t2
C  01C:02FBt2
C  01C:02FEt2
C  01C:0301t2
C  01C:0304t2
C  01C:0307t2
C  01C:030At2
C  01C:030Dt2
C  01C:0310t2
C  01C:0313t2
C  01C:0316t2
C  01C:0319t2
C  01C:031Ct1
C  01C:031Ft1
```

```
XA(4,2, 6)= .90000E+00
XA(4,2, 7)= .10500E+01
XA(4,2, 8)= .14000E+01
XA(4,2, 9)= .16500E+01
XA(4,2,10)= .18500E+01
XA(4,2,11)= .20800E+01
XA(4,2,12)= .23000E+01
XA(4,3, 1)=0.
XA(4,3, 2)= .40000E+00
XA(4,3, 3)= .10000E+01
XA(4,3, 4)= .22500E+01
XA(4,3, 5)= .34000E+01
XA(4,3, 6)= .45000E+01
XA(4,3, 7)= .55000E+01
XA(4,3, 8)= .65000E+01
XA(4,3, 9)= .77000E+01
XA(4,3,10)= .86000E+01
XA(4,3,11)= .97500E+01
XA(4,3,12)= .11000E+02
XA(4,4, 1)= .80000E+00
XA(4,4, 2)= .16000E+01
XA(4,4, 3)= .32000E+01
XA(4,4, 4)= .59000E+01
XA(4,4, 5)= .82000E+01
XA(4,4, 6)= .10300E+02
XA(4,4, 7)= .12500E+02
XA(4,4, 8)= .14700E+02
XA(4,4, 9)= .16900E+02
XA(4,4,10)= .19200E+02
XA(4,4,11)= .21300E+02
XA(4,4,12)= .23500E+02
XA(4,5, 1)= .19500E+01
XA(4,5, 2)= .41000E+01
XA(4,5, 3)= .70000E+01
XA(4,5, 4)= .10200E+02
XA(4,5, 5)= .12700E+02
XA(4,5, 6)= .15400E+02
XA(4,5, 7)= .18000E+02
XA(4,5, 8)= .20500E+02
XA(4,5, 9)= .23200E+02
XA(4,5,10)= .25800E+02
XA(4,5,11)= .28416E+02
XA(4,5,12)= .31038E+02
XA(4,6, 1)= .37500E+01
XA(4,6, 2)= .67000E+01
XA(4,6, 3)= .87000E+01
XA(4,6, 4)= .10300E+02
XA(4,6, 5)= .12200E+02
XA(4,6, 6)= .14300E+02
XA(4,6, 8)= .18450E+02
XA(4,6, 7)= .16400E+02
XA(4,6, 9)= .20500E+02
XA(4,6,10)= .22500E+02
XA(4,6,11)= .24600E+02
XA(4,6,12)= .26500E+02
XA(4,7, 1)= .77000E+01
XA(4,7, 2)= .78000E+01
XA(4,7, 3)= .78000E+01
XA(4,7, 4)= .90000E+01
XA(4,7, 6)= .11700E+02
```

```
C  01C1032A11
C  01C1032511
C  01C1032011
C  01C1032B11
C  01C1032E11
C  01C1033311
C  01C1033911
C  01C1033711
C  01C1033C12
C  01C1033B11
C  01C1033E12
C  01C1033F11
C  01C1034211
C  01C1034511
C  01C1034811
C  01C1034B11
C  01C1034E11
C  01C1035111
C  01C1035411
C  01C1035D14
C  01C1035011
C  01C1035811
C  01C1035E11
C  01C1036111
C  01C1036411
C  01C1036711
C  01C1036A11
C  01C1036D11
C  01C1037011
C  01C1037311
C  01C1037611
C  01C1037911
C  01C1037C11
C  01C1037F11
C  01C1038013
C  01C1038311
C  01C1038611
C  01C1038911
C  01C1038A14
C  01C1038D11
C  01C1039011
C  01C1039311
C  01C1039611
C  01C1039911
C  01C1039C11
C  01C1039F11
C  01C103A211
C  01C103A511
C  01C103A811
C  01C103AB11
C  01C103AE11
C  01C103B111
C  01C103B411
C  01C103B711
C  01C103BA11
C  01C103BD11
C  01C103C011
C  01C103C311
C  01C103C611
C  01C103C713
```

```
XA(4,7, 7)= .13100E+02
XA(4,7, 8)= .14450E+02
XA(4,7, 9)= .15800E+02
XA(4,7,10)= .17100E+02
XA(4,7,11)= .18300E+02
XA(4,7,12)= .19500E+02
XA(5,1, 1)=-.26500E+00
XA(5,1, 2)=-.32500E+00
XA(5,1, 3)=-.37500E+00
XA(5,1, 4)=-.45000E+00
XA(5,1, 5)=-.52500E+00
XA(5,1, 6)=-.63000E+00
XA(5,1, 7)=-.74000E+00
XA(5,1, 8)=-.83800E+00
XA(5,1, 9)=-.96000E+00
XA(5,1,10)=-.11000E+01
XA(5,1,11)=-.12350E+01
XA(5,1,12)=-.15370E+01
XA(5,2, 1)=0.
XA(5,2, 2)= .25000E+00
XA(5,2, 3)= .60000E+00
XA(5,2, 4)= .12500E+01
XA(5,2, 5)= .18700E+01
XA(5,2, 6)= .25000E+01
XA(5,2, 7)= .30500E+01
XA(5,2, 8)= .38300E+01
XA(5,2, 9)= .42000E+01
XA(5,2,10)= .47500E+01
XA(5,2,11)= .52500E+01
XA(5,2,12)= .58000E+01
XA(5,3, 1)= .45000E+00
XA(5,3, 2)= .90000E+00
XA(5,3, 3)= .19000E+01
XA(5,3, 4)= .37000E+01
XA(5,3, 5)= .53000E+01
XA(5,3, 6)= .69000E+01
XA(5,3, 7)= .84000E+01
XA(5,3, 8)= .99500E+01
XA(5,3, 9)= .11500E+02
XA(5,3,10)= .13200E+02
XA(5,3,11)= .14800E+02
XA(5,3,12)= .16600E+02
XA(5,4, 1)= .12000E+01
XA(5,4, 2)= .23000E+01
XA(5,4, 3)= .45000E+01
XA(5,4, 4)= .80000E+01
XA(5,4, 5)= .11000E+02
XA(5,4, 6)= .13900E+02
XA(5,4, 7)= .16500E+02
XA(5,4, 8)= .19300E+02
XA(5,4, 9)= .22000E+02
XA(5,4,10)= .24700E+02
XA(5,4,11)= .27455E+02
XA(5,4,12)= .30207E+02
XA(5,5, 1)= .27000E+01
XA(5,5, 2)= .54000E+01
XA(5,5, 3)= .90000E+01
XA(5,5, 4)= .12450E+02
XA(5,5, 5)= .15300E+02
XA(5,5, 6)= .18300E+02
```

```
C  01C103CA11
C  01C103CB11
C  01C103D011
C  01C103D311
C  01C103D611
C  01C103D911
C  01C103DC11
C  01C103DF12
C  01C103E212
C  01C103E512
C  01C103E812
C  01C103EB12
C  01C103EE12
C  01C103F112
C  01C103F412
C  01C103F712
C  01C103FA12
C  01C103FD12
C  01C104D012
C  01C104011J
C  01C104041I
C  01C104071I
C  01C104DA1I
C  01C104DD1I
C  01C1041011
C  01C1041311
C  01C1041611
C  01C1041911
C  01C1042211
C  01C1042511
C  01C1042811
C  01C1042B11
C  01C1042E11
C  01C1043111
C  01C1043411
C  01C1043711
C  01C1043A11
C  01C1043D11
C  01C1044011
C  01C1044311
C  01C1044611
C  01C1044911
C  01C1044C11
C  01C1044F11
C  01C1045013
C  01C1045115
C  01C1045411
C  01C1045711
C  01C1045A11
C  01C1045B14
C  01C1045E11
C  01C1046111
C  01C1046411
C  01C1046711
C  01C1046A11
C  01C1046D13
C  01C1046E11
C  01C1047111
```

```
XA(5,5, 7)= .21200E+02
XA(5,5, 8)= .24300E+02
XA(5,5, 9)= .27300E+02
XA(5,5,10)= .30357E+02
XA(5,5,11)= .33429E+02
XA(5,5,12)= .36523E+02
XA(5,6, 1)= .49500E+01
XA(5,6, 2)= .85000E+01
XA(5,6, 3)= .10600E+02
XA(5,6, 4)= .12400E+02
XA(5,6, 5)= .14700E+02
XA(5,6, 6)= .17000E+02
XA(5,6, 7)= .19400E+02
XA(5,6, 8)= .21700E+02
XA(5,6, 9)= .24000E+02
XA(5,6,10)= .26224E+02
XA(5,6,11)= .28414E+02
XA(5,6,12)= .30579E+02
XA(5,7, 1)= .90500E+01
XA(5,7, 2)= .91500E+01
XA(5,7, 3)= .90000E+01
XA(5,7, 4)= .10400E+02
XA(5,7, 5)= .11900E+02
XA(5,7, 6)= .13300E+02
XA(5,7, 7)= .14800E+02
XA(5,7, 8)= .16300E+02
XA(5,7, 9)= .17700E+02
XA(5,7,10)= .19200E+02
XA(5,7,11)= .20550E+02
XA(5,7,12)= .21900E+02
XA(6,1, 1)=-.17000E+00
XA(6,1, 2)=-.15000E+00
XA(6,1, 3)=-.10000E+00
XA(6,1, 4)=0.
XA(6,1, 5)= .70000E-01
XA(6,1, 6)= .11000E+00
XA(6,1, 7)= .15000E+00
XA(6,1, 8)= .20000E+00
XA(6,1, 9)= .23000E+00
XA(6,1,10)= .25000E+00
XA(6,1,11)= .26000E+00
XA(6,1,12)= .30000E+00
XA(6,2, 1)= .20000E+00
XA(6,2, 2)= .48000E+00
XA(6,2, 3)= .10500E+01
XA(6,2, 4)= .21000E+01
XA(6,2, 5)= .30500E+01
XA(6,2, 6)= .39500E+01
XA(6,2, 7)= .48500E+01
XA(6,2, 8)= .57000E+01
XA(6,2, 9)= .65000E+01
XA(6,2,10)= .72000E+01
XA(6,2,11)= .79500E+01
XA(6,2,12)= .86500E+01
XA(6,3, 1)= .70000E+00
XA(6,3, 2)= .13000E+01
XA(6,3, 3)= .27000E+01
XA(6,3, 4)= .51000E+01
XA(6,3, 5)= .72000E+01
XA(6,3, 6)= .92000E+01
```

```
C  01C:0474:11
C  01C:0477:11
C  01C:047A:11
C  01C:047D:11
C  01C:0480:11
C  01C:0483:11
C  01C:0486:11
C  01C:0489:11
C  01C:048C:11
C  01C:048F:11
C  01C:0492:11
C  01C:0495:11
C  01C:0498:14
C  01C:049B:11
C  01C:049E:11
C  01C:04A1:14
C  01C:04A4:11
C  01C:04A7:11
C  01C:04AA:11
C  01C:04AD:13
C  01C:04B0:11
C  01C:04B3:11
C  01C:04B6:11
C  01C:04B9:11
C  01C:04BC:11
C  01C:04BF:11
C  01C:04C2:11
C  01C:04C5:11
C  01C:04C8:11
C  01C:04CB:12
C  01C:04CE:12
C  01C:04D1:12
C  01C:04D2:13
C  01C:04D5:11
C  01C:04D8:11
C  01C:04DB:11
C  01C:04DE:11
C  01C:04E1:11
C  01C:04E4:11
C  01C:04E7:11
C  01C:04EA:11
C  01C:04ED:11
C  01C:04F0:11
C  01C:04F3:11
C  01C:04F6:11
C  01C:04F9:11
C  01C:04FC:11
C  01C:04FF:11
C  01C:0502:11
C  01C:0505:11
C  01C:0508:11
C  01C:050B:11
C  01C:050E:11
C  01C:0511:11
C  01C:0514:11
C  01C:0517:11
C  01C:051A:11
C  01C:051D:11
```

```
      XA(6,3, 7)= .11140E+02                                                    C  01C:052U11
      XA(6,3, 8)= .13050E+02                                                    C  01C:052311
      XA(6,3, 9)= .15140E+02                                                    C  01C:052011
      XA(6,3,10)= .17200E+02                                                    C  01C:052V11
      XA(6,3,11)= .19340E+02                                                    C  01C:052611
      XA(6,3,12)= .21700E+02                                                    C  01C:052F11
      XA(6,4, 1)= .16540E+01                                                    C  01C:053211
      XA(6,4, 2)= .31000E+01                                                    C  01C:053311
      XA(6,4, 3)= .59000E+01                                                    C  01C:053011
      XA(6,4, 4)= .10200E+02                                                    C  01C:053U11
      XA(6,4, 5)= .13700E+02                                                    C  01C:053611
      XA(6,4, 6)= .17000E+02                                                    C  01C:054111
      XA(6,4, 7)= .20200E+02                                                    C  01C:054214
      XA(6,4, 8)= .23300E+02                                                    C  01C:054311
      XA(6,4, 9)= .26000E+02                                                    C  01C:054011
      XA(6,4,10)= .28907E+02                                                    C  01C:054V14
      XA(6,4,11)= .31830E+02                                                    C  01C:054611
      XA(6,4,12)= .34775E+02                                                    C  01C:054F11
      XA(6,5, 1)= .37000E+01                                                    C  01C:055211
      XA(6,5, 2)= .70000E+01                                                    C  01C:055311
      XA(6,5, 3)= .10700E+02                                                    C  01C:055013
      XA(6,5, 4)= .14400E+02                                                    C  01C:055V11
      XA(6,5, 5)= .17600E+02                                                    C  01C:055611
      XA(6,5, 6)= .21000E+02                                                    C  01C:055F11
      XA(6,5, 7)= .24500E+02                                                    C  01C:056014
      XA(6,5, 8)= .27700E+02                                                    C  01C:056311
      XA(6,5, 9)= .30843E+02                                                    C  01C:056011
      XA(6,5,10)= .33947E+02                                                    C  01C:056V11
      XA(6,5,11)= .37026E+02                                                    C  01C:056611
      XA(6,5,12)= .40088E+02                                                    C  01C:056F11
      XA(6,6, 1)= .63000E+01                                                    C  01C:057211
      XA(6,6, 2)= .10000E+02                                                    C  01C:057511
      XA(6,6, 3)= .12200E+02                                                    C  01C:057013
      XA(6,6, 4)= .14000E+02                                                    C  01C:057911
      XA(6,6, 5)= .16500E+02                                                    C  01C:057A13
      XA(6,6, 6)= .19100E+02                                                    C  01C:057U11
      XA(6,6, 7)= .21600E+02                                                    C  01C:058V11
      XA(6,6, 8)= .24200E+02                                                    C  01C:058311
      XA(6,6, 9)= .26800E+02                                                    C  01C:058011
      XA(6,6,10)= .29315E+02                                                    C  01C:058V11
      XA(6,6,11)= .31794E+02                                                    C  01C:058611
      XA(6,6,12)= .34245E+02                                                    C  01C:058F11
      XA(6,7, 1)= .10800E+02                                                    C  01C:059211
      XA(6,7, 2)= .10600E+02                                                    C  01C:059511
      XA(6,7, 3)= .10600E+02                                                    C  01C:059011
      XA(6,7, 4)= .12100E+02                                                    C  01C:059U11
      XA(6,7, 5)= .13700E+02                                                    C  01C:059611
      XA(6,7, 6)= .15400E+02                                                    C  01C:05A111
      XA(6,7, 7)= .17100E+02                                                    C  01C:05A411
      XA(6,7, 8)= .18800E+02                                                    C  01C:05A711
      XA(6,7, 9)= .20500E+02                                                    C  01C:05AA11
      XA(6,7,10)= .22200E+02                                                    C  01C:05AU11
      XA(6,7,11)= .23700E+02                                                    C  01C:05BV11
      XA(6,7,12)= .25700E+02                                                    C  01C:05B311
C           END ASSIGNMENT OF VALUES TO ARRAY XA                                C  01C:05B011
C           DETERMINE IF (=LARGEST INTEGER SUCH THAT FF(IF) .LE. F)             C  01C:05B011
      IF(I-3.)20,21,21                                                          C  01C:05B011
   20 WRITE(6,101)                                                              C  01C:05B713
      WRITE(6,102)F                                                             C  01C:05B012
      GOTO199                                                                   C  01C:05C212
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      IF(F-5.)22,23,23                                                  C  01C:05C415
22    IF=1                                                              C  01C:05C411
      GUTU35                                                            C  01C:05C415
23    IF(F-7.)24,25,25                                                  C  01C:05C512
24    IF=2                                                              C  01C:05C614
      GUTU35                                                            C  01C:05C713
25    IF(F-10.)26,27,27                                                 C  01C:05C810
26    IF=3                                                              C  01C:05C912
      GUTU35                                                            C  01C:05CA11
27    IF(F-15.)28,29,29                                                 C  01C:05CA14
28    IF=4                                                              C  01C:05CC10
      GUTU35                                                            C  01C:05CC15
29    IF(F-20.)30,31,31                                                 C  01C:05CD12
30    IF=5                                                              C  01C:05CE14
      GUTU35                                                            C  01C:05CF13
31    IF(F-30.)32,33,34                                                 C  01C:05D010
32    IF=6                                                              C  01C:05D312
      GUTU35                                                            C  01C:05D411
33    IF=7                                                              C  01C:05D414
      GUTU35                                                            C  01C:05D513
34    WRITE(6,101)                                                      C  01C:05D610
      WRITE(6,102)F                                                     C  01C:05DA12
      GUTU199                                                           C  01C:05E112
35    CONTINUE                                                          C  01C:05E415
C           END DETERMINATION OF INTEGER IF                             C  01C:05E415
C           DETERMINE IM (=LARGEST INTLGER SUCH THAT RM(IM) .LE. R)     C  01C:05E415
      IF(R-25.)40,41,41                                                 C  01C:05E415
40    WRITE(6,101)                                                      C  01C:05E811
      WRITE(6,103)R                                                     C  01C:05EF12
      GUTU199                                                           C  01C:05EE12
41    IF(R-50.)42,43,43                                                 C  01C:05EE15
42    IM=1                                                              C  01C:05FU11
      GUTU65                                                            C  01C:05FU15
43    IF(R-100.)44,45,45                                                C  01C:05F112
44    IM=2                                                              C  01C:05F214
      GUTU65                                                            C  01C:05F313
45    IF(R-200.)46,47,47                                                C  01C:05F410
46    IM=3                                                              C  01C:05F512
      GUTU65                                                            C  01C:05F611
47    IF(R-300.)48,49,49                                                C  01C:05F614
48    IM=4                                                              C  01C:05F811
      GUTU65                                                            C  01C:05F910
49    IF(R-400.)50,51,51                                                C  01C:05F913
50    IM=5                                                              C  01C:05FB10
      GUTU65                                                            C  01C:05FB15
51    IF(R-500.)52,53,53                                                C  01C:05FC12
52    IM=6                                                              C  01C:05FU15
      GUTU65                                                            C  01C:05FE14
53    IF(R-600.)54,55,55                                                C  01C:05FF11
54    IM=7                                                              C  01C:060U14
      GUTU65                                                            C  01C:060113
55    IF(R-700.)56,57,57                                                C  01C:060210
56    IM=8                                                              C  01C:060313
      GUTU65                                                            C  01C:060412
57    IF(R-800.)58,59,59                                                C  01C:060415
58    IM=9                                                              C  01C:060612
      GUTU65                                                            C  01C:060711
59    IF(R-900.)60,61,61                                                C  01C:060714
60    IM=10                                                             C  01C:060914
      GUTU65                                                            C  01C:060A13
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 61   IF(R-1000.)62,63,64                                                    C  01C1060B10
 62   IR=11                                                                  C  01C1060E13
      GUTU65                                                                 C  01C1060F12
 63   IR=12                                                                  C  01C1060F15
      GUTU65                                                                 C  01C1061U14
 64   WRITE(6,101)                                                           C  01C1061111
      WRITE(6,103)R                                                          C  01C1061512
      GUTU199                                                                C  01C1061612
 65   CUNTINUE                                                               C  01C1061615
C          END DETERMINATION UF INTEGER IR                                   C  01C1061615
      D=B1*(F**B2)*EXP(B3*(F**5))                                            C  01C1061615
      E=F1*(F**E2)                                                           C  01C1062211
      XLBASC=20.*ALUG10(62.*PI*R*F)/2.3)+D*(R**E)                            C  01C1062415
      DIF=1./(FF(IF+1)-FF(IF))                                               C  01C1062612
      DIR=1./(RR(IR+1)-RR(IR))                                               C  01C1062F10
      Z1=XA(IS,IF,IR)+DIF*(XA(IS,IF+1,IR)-XA(IS,IF,IR))*(F-FF(IF))           C  01C1063114
      Z2=XA(IS,IF,IR+1)+DIF*(XA(IS,IF+1,IR+1)-XA(IS,IF,IR+1))*(F-FF(IF))     C  01C1063E11
      XLADD=Z1+DIR*(Z2-Z1)*(R-RR(IR))                                        C  01C1064A13
      GATTEN=XLBASC+XLADD                                                    C  01C1064E13
      GUTU200                                                                C  01C1064F15
 101  FURMAT(1X)                                                             C  01C1065U12
 102  FURMAT(1X,'******WARNING: THE FREQUENCY ',F8.4,' MHZ. LIES OUTSIDE     C  01C1065U12
     1THE REGION RECUMMENDED FUR INTERPOLATION*****')                        C  01C1065U12
 103  FURMAT(1X,'****** WARNING: THE RANGE',F9.2,' KM. LIES OUTSIDE THE R    C  01C1065U12
     1EGION RECOMMENDED FOR INTERPOLATION *****')                            C  01C1065U12
 199  GATTEN=10000.                                                          C  01C1065U12
 200  RETURN                                                                 C  01C1065112
      END                                                                    C  01C1065115
```